MY AUTOMOBILE

ITS OPERATION
CARE AND REPAIR

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MY AUTOMOBILE:
ITS OPERATION, CARE, AND REPAIR

MY AUTOMOBILE:

ITS OPERATION, CARE, AND REPAIR

An Indispensable Handbook for Automobile Owners and Drivers, Fully Describing the Care and Operation of All Types of Cars and Giving Step-by-Step Instruction for Finding and Curing Trouble of Every Description

BY

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"Electrical Equipment of the Automobile,"
and other Publications

SECOND EDITION
COMPLETELY REVISED AND ENTIRELY RESET

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PREFACE TO SECOND EDITION

Although the fundamentals of automobile construction have not changed materially since the first edition of this book was issued in 1924, there have been many alterations in detail. Consequently, the second edition has been extensively revised; much of the text has been rewritten and most of the illustrations are new.

It is the first book to describe front-wheel drive automobiles; the discussion of this subject is complete and includes a frank treatment of the advantages and disadvantages of front-drive construction.

Chapters have been added completely describing the construction of the Ford Model "A," and much space is devoted to methods of repair. This car, of course, does not differ fundamentally from other cars, but because of its extensive use, complete instructions are given for repairing and adjusting those units which differ somewhat from those found in other makes of cars.

This book has been written for two classes of people:

1. Those with little or no mechanical ability, but who desire easily understandable, step-by-step instructions for finding and curing trouble.

2. Those who are mechanically inclined and who wish to acquire a thorough knowledge of how any car works, troubles to expect and how to cure them.

The book is also especially suitable for students, taxicab and truck drivers, and to all those entering the automotive industry, including automobile salesmen, accessory storekeepers, automobile mechanics, and the like.

It is believed to be the only book of its kind giving specific, step-by-step directions for finding troubles. Each trouble is treated according to its Symptom, such as missing, headlights dead, rear-axle hums, and so forth. The possible Causes of the trouble are briefly listed in their proper order under each Symptom and the Cures follow the Causes. By observing the directions given in Cure-1, Cure-2, Cure-3, etc., the trouble may be determined quickly by almost anyone, regardless of previous experience, or whether he has read the book or not.

The book, therefore, may be used as a trouble finder, exactly as you would use a road guide when touring. It may be placed in one of the door pockets of a car for immediate reference when trouble arises. Its use will permit many motorists who are now afraid to venture off main roads for fear of getting stuck to ramble over the country at will.

The book is particularly intended for those who wish to make minor repairs and adjustments; it does not assume that anybody and everybody is capable of making extensive repairs. Where repair work is likely to prove unsatisfactory unless done by an experienced mechanic with the proper equipment, the reader is advised to seek a repair-shop.

HAROLD F. BLANCHARD, M. E.

New York, N. Y., March, 1930.

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My Automobile: Its Operation, Care, and Repair

Chapter I

MECHANISM OF THE AUTOMOBILE

SOURCE OF POWER

1. The ordinary gasoline automobile is a machine for transporting 2 to 7 passengers (an average of two is carried throughout the United States) over approximately smooth surfaces at relatively high rates of speed. It is driven by an engine which converts the heat energy of gasoline into a rotary motion which is transmitted to the rear wheels. Gasoline is vaporized and mixed with air in the carburetor and then is drawn into the cylinders of the engine where it is ignited (exploded) by electric sparks. The burned or exhaust gases pass out from the engine into the muffler, whence they escape to the atmosphere. The explosions occur with great rapidity. At 20 miles an hour each cylinder produces about 500 explosions a minute, so if the engine has four cylinders it produces a total of 2,000 explosions a minute.

2. The effect of the explosions is to rotate the main shaft of the engine, called the crankshaft. Production of power may be varied to meet the demands of the moment by opening or closing the throttle, which is a damper, similar to the damper in a stove-pipe. The throttle is controlled by a lever on the steering wheel, a pedal, or both. When the throttle is wide open the cylinders take in full charges of gasoline and air; when it is closed as far as it will go, the cylinders get so little mixture that the engine will barely run idly, much less pull the car.

STARTING MECHANISM

3. Unlike the steam engine or the electric motor, the gasoline engine, ordinarily, can not start itself. To start, it is necessary to rotate the engine by hand or by some starting device. The engine may be stopped by switching off the ignition system, which is the name of the electrical mechanism that produces the sparks in the cylinders. Before the engine can be started again the ignition must be switched on.

CLUTCH

4. Inasmuch as the gasoline engine must be running before the car can be put into motion, it is necessary to have a device to connect the engine crankshaft with the driving mechanism running to the rear wheels. It is called a clutch because it clutches the crankshaft. When the clutch is engaged the engine drives the car, and when disengaged, the engine runs independently, with the car either standing still or coasting.

TRANSMISSION

5. As a rule, just back of the clutch is the transmission, a device which ordinarily gives three gear ratios forward and one reverse. There is a relatively high gear which is used when traveling along the level or up moderate hills, an intermediate gear for steeper hills, and a very low gear for steepest hills, deep sand, mud, and starting. Reverse gear is usually lower than the lowest forward gear. These gear ratios are generally spoken of as high, intermediate, low, and reverse, or third, second, first, and reverse.

6. On high gear the engine may make 4 or 5 revolutions to 1 revolution of the rear wheels; on intermediate, about 7 or 8 revolutions; and on low gear, about 14. For level roads and moderate hills high gear is adequate, but if, for example, a hill is too steep for high gear, intermediate must be used, because the engine can run faster on intermediate gear and therefore develops more power. Likewise, on a steep hill, low gear may be required.

7. As the engine has a minimum speed of about 200 revolutions a minute, the slowest the car can be run on high gear is about 4 miles an hour, and if a slower speed is desired, intermediate gear must be used with a minimum speed of about 2.5 miles an hour. If this is not slow enough, low speed must be employed, giving a minimum speed of about 1 mile per hour. If a still lower rate is needed, as in moving the car an inch or so, the clutch must be slipped. It must not be forgotten, throughout this discussion, that the aim is to give a rather complete picture of a typical automobile, and all figures and statements, such as above, apply to the average.

REAR AXLE

8. From the transmission the power is carried back to the rear axle by a shaft known as the drive or propeller shaft. In the center of the rear-axle housing are a number of gears including the two bevel gears and the differential gears. The bevel gears transmit the engine power from the drive shaft to the shafts connected to the rear wheels. The differential gears come into action automatically when rounding a corner, and compensate for the

fact that in making a turn the outside wheel must always rotate faster than the inside wheel, because it has farther to go.

9. Figure 1 shows the position of the principal units that have just been described, as well as some others. Their position and appearance should be noted.

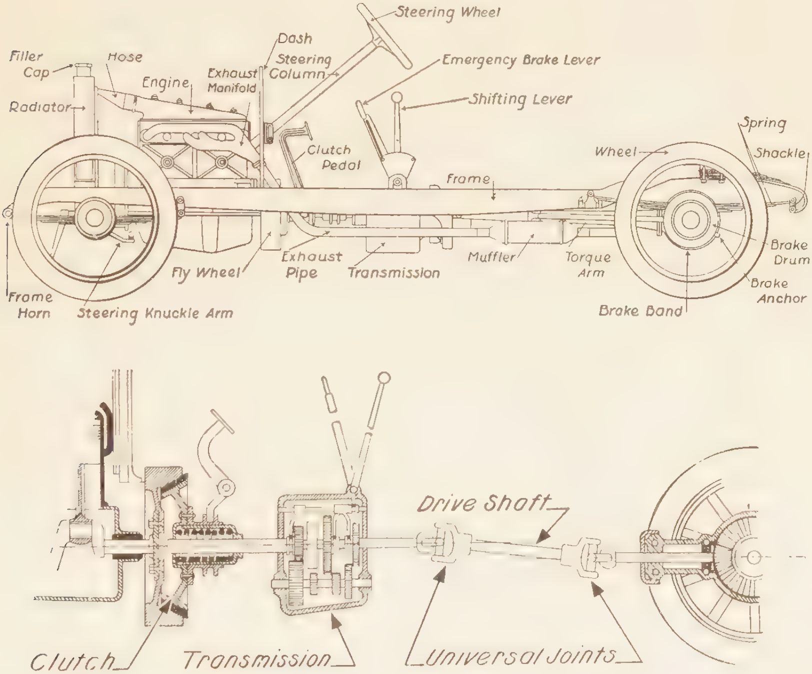
Steering Wheel
Dash
Steering Column
Emergency Brake Lever
Filler Cap
Hose
Engine
Exhaust Manifold
Radiator
Shifting Lever
Spring
Clutch Pedal
Wheel
Shackle
Frame
Brake Drum
Exhaust Pipe
Transmission
Muffler
Torque Arm
Fly Wheel
Brake Anchor
Frame Horn
Steering Knuckle Arm
Brake Band
Drive Shaft
Clutch
Transmission
Universal Joints

Figure 1.—Principal units of an automobile

THE ENGINE

10. The engine is logically the first unit to be described. For simplicity it is advisable to consider a single-cylinder engine first (Figure 2). To illustrate the internal mechanism, the drawing shows how such an engine would look if split in two vertically. It is plain that the piston is an inverted cup-shaped device which slides up and down in the cylinder. Its motion causes the crankshaft to rotate, the piston being linked to the crankshaft by the connecting-rod. The upper end of the connecting-rod is pivoted to the piston by means of a piston pin or wristpin, while the lower end of the connecting-rod is connected by a bearing to a crank on the engine shaft (crankshaft). Therefore as the crankshaft rotates, the piston moves up and down. The crankshaft is mounted in bearings in the crankcase.

THE CYCLE OF OPERATION

11. An explosion is obtained every two revolutions of the crankshaft; the piston, of course, makes one down stroke and one up stroke during each revolution. In other words, the piston makes four strokes in every two revolutions; the terms applied to these strokes are suction, compression, explosion, exhaust. (See Figure 3.) On the suction stroke the intake valve is open and the piston, moving down, draws in a mixture of vaporized gasoline and air from the carburetor. When the piston starts back up on the compression stroke the intake valve closes, with the result that the charge is compressed to 80 to 100 pounds pressure by the time the piston gets to the top. Approximately at this instant a spark jumps across the points of the spark-plug and ignites the mixture; the flame spreads so rapidly that the action is usually referred to as an explosion. The temperature of the burning gases jumps as high as 3,000° F., consequently the pressure rises to 350 or 500 pounds per

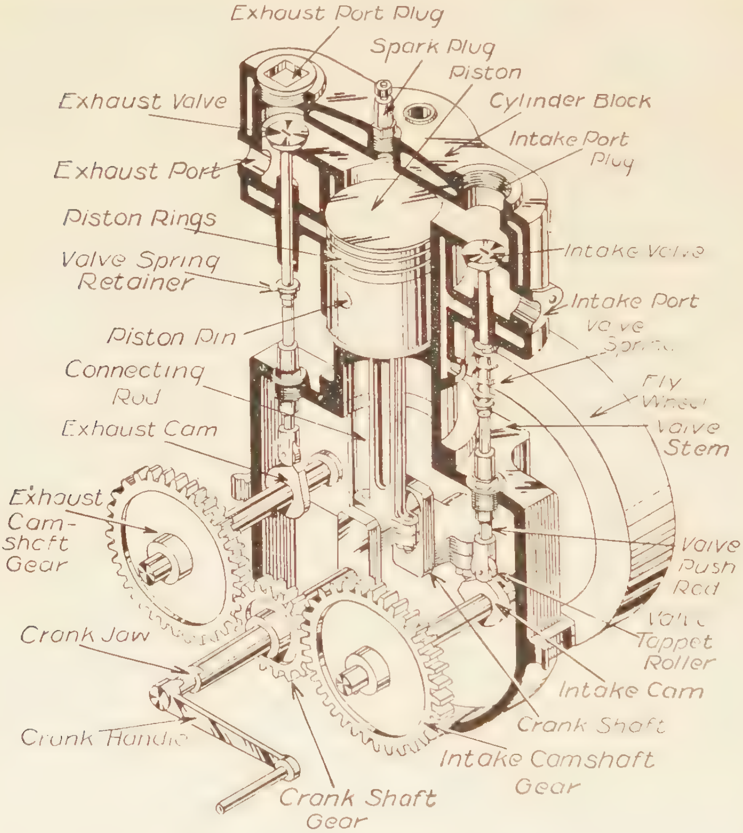
Exhaust Port Plug
Spark Plug
Piston
Cylinder Block
Exhaust Valve
Intake Port Plug
Exhaust Port
Piston Rings
Intake Valve
Valve Spring Retainer
Intake Port
Valve Spring
Piston Pin
Connecting Rod
Fly Wheel
Exhaust Cam
Valve Stem
Exhaust Cam-shaft Gear
Valve Push Rod
Valve Tappet Roller
Crank Jaw
Intake Cam
Crank Shaft
Crank Handle
Intake Camshaft Gear
Crank Shaft Gear

Figure 2.—A single-cylinder engine

square inch. This force, pushing down on the piston, develops the power. As the piston moves down on the explosion stroke, the gases expand and the pressure drops, partly because of the expansion and partly because of loss in temperature to the cylinder walls. With the gases at such a high temperature, heat is quickly absorbed by the relatively cool cylinder walls. These walls have water circulating through them so that: (1) the expansion of cylinder and piston due to heating will be kept down within reasonable limits; (2) the lubricating oil between cylinder and piston will not become vaporized; and (3) the cylinder will not become so hot as to ignite the mixture before the spark-plug delivers its spark. Before the piston reaches the bottom of the explosion stroke the exhaust valve opens, and then as the piston moves up on the exhaust stroke it forces most of the burned gases out through the exhaust valve into the exhaust pipe. By this time the gases are relatively cool. Then the piston starts on a new intake stroke and the whole performance or cycle is repeated, and so on. Some exhaust gas remains in the combustion chamber, but by the time the intake valve opens, this gas is too cool to ignite the incoming charge.

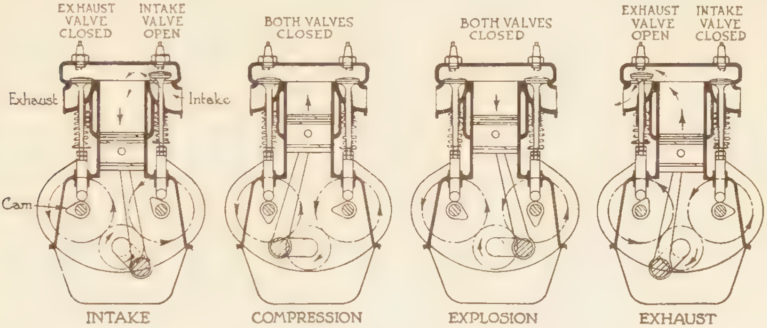

Figure 3.—Diagram illustrating the four strokes of an automobile engine

COMPRESSION AND ITS EFFECT

12. Recently, high-compression engines have become popular. The term "high compression" means that the engine has a compression ratio of 5 or 6 to 1 as compared to 4 to 1 which was common not so long ago. The term "compression ratio" means the ratio of the total cylinder volume with the piston at the bottom of the stroke divided by the total cylinder volume with the piston at the top of the stroke. In other words, if the total volume of the cylinder with the piston at the bottom is 60 inches, whereas the volume of the cylinder, or more accurately the combustion chamber, is 12 inches with the piston at the top of the stroke, the compression ratio is 5 to 1; that is, 60

divided by 12. Obviously, the greater the compression ratio the more the mixture is compressed.

13. The higher the compression ratio the greater the power which the engine develops and the greater the fuel economy. However, the compression ratio can not be increased indefinitely because when it is raised beyond a certain point, detonation, commonly called "spark knock" or "carbon knock," occurs, with resultant loss of power and fuel economy; therefore the compression ratio must not be made so high that detonation will occur. Some shapes of cylinder heads will permit higher compression than others without detonation; other factors influence this question, such as position of spark-plug and valves, effectiveness of cooling of the combustion chamber, etc. As explained in paragraph 55, two spark-plugs at opposite sides of the combustion chamber will also reduce the tendency of detonation and thus permit a higher compression ratio. This construction is used particularly on overhead valve engines; it is also desirable on a T-head engine.

14. The tendency to detonate increases as carbon accumulates and if the compression ratio is a little too high for a given fuel, it may be necessary to remove carbon at say 5,000 miles, whereas if the compression ratio in this engine with this fuel were a little less it might not be necessary to remove carbon in less than 15,000 or 20,000 miles.

15. Some engines properly have such a high compression ratio that they will invariably detonate on so-called standard fuels, therefore high-compression fuels must be used in these engines to eliminate detonation. Similarly, if an engine designed to run without detonation on standard fuel detonates due to an accumulation of carbon, detonation may be eliminated for a considerable period by using a high-compression fuel.

VALVES

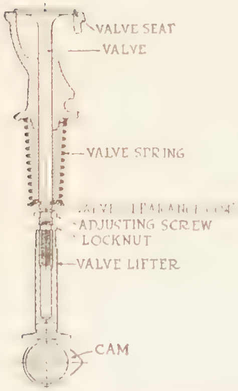

Figure 4. Valve mechanism for an L- or T-head engine

16. Figure 4 is a close-up view of a valve. The opening and closing of both the intake and the exhaust valves is effected by rotating *cams*. As clearly shown (Figure 2), a cam is an irregular projection on the *camshaft*, of such a size and shape that the valves are opened and closed by it at the right time. In the illustration, there are separate camshafts for intake and exhaust valves. Each camshaft is driven by gear from the crankshaft. As each valve opens only once every two revolutions, the camshaft gears are twice the size of the gear on the crankshaft, therefore the camshaft always revolves at half the speed of the crankshaft. The camshaft is mounted in bearings in the crank-

case. As metal-to-metal gears are likely to become noisy, the camshaft gear is often made of a non-metallic composition consisting of highly compressed canvas impregnated with bakelite, or some similar composition. Another method of reducing the noise is to use a "silent-type" chain, as in Figure 5.

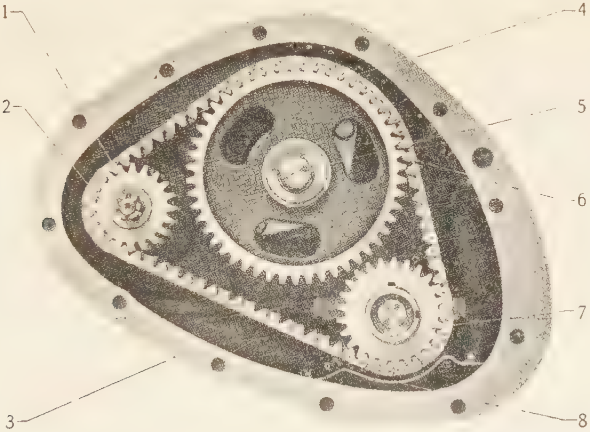

Figure 5.—Timing chain and sprockets:

1—Generator sprocket nut	*5*—Camshaft sprocket screw
2—Generator sprocket	*6*—Drive chain
3—Chain case	*7*—Crankshaft sprocket
4—Camshaft sprocket	*8*—Chain guide

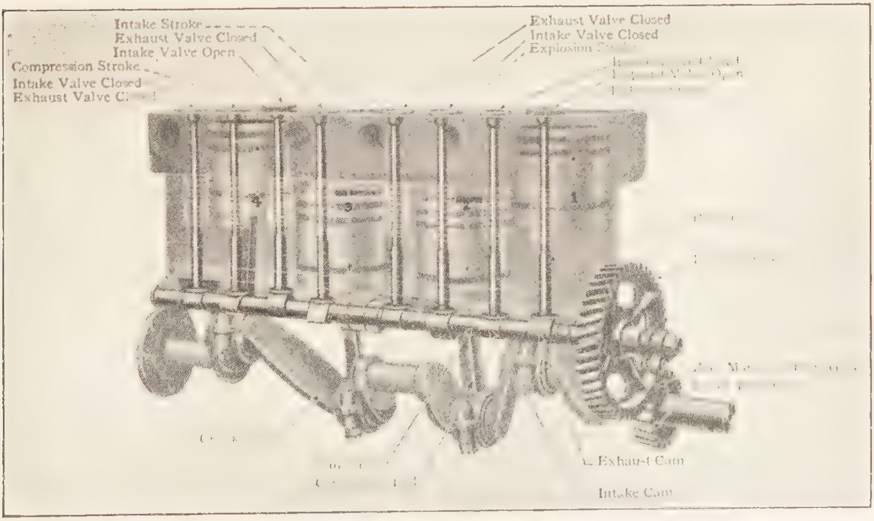
Intake Stroke
Exhaust Valve Closed
Intake Valve Open
Compression Stroke
Intake Valve Closed
Exhaust Valve Closed
Exhaust Valve Closed
Intake Valve Closed
Explosion Stroke
4
3
2
1
Exhaust Cam
Intake Cam

Figure 6.—Partly assembled L-head Ford Model T engine showing cylinder block, pistons, connecting-rods, crankshaft, camshaft, and valve mechanism

CAMSHAFTS

17. The operation of the valve mechanism should now be clear. The rotation of the crankshaft rotates the camshafts. The camshafts are carefully set with respect to the crankshaft, and the cams are just the right size and shape so that each valve opens and closes at the right time. The valve has a strong spring which tends to hold it closed, and thus the movement of the valve conforms exactly to the shape of the cam.

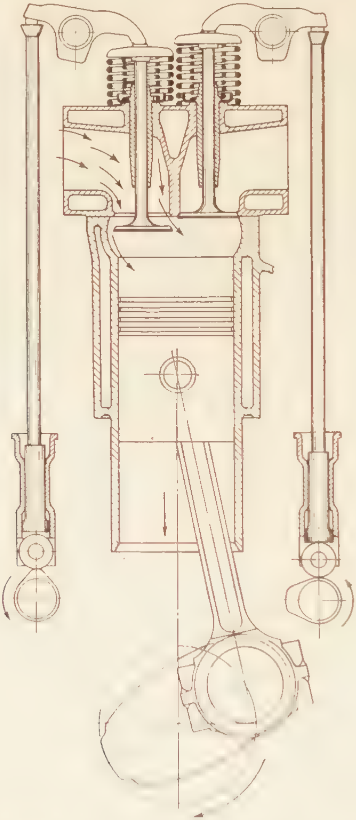

Figure 7—Valve in head engine. In practice, the valves are placed side by side lengthwise of the engine instead of crosswise as shown; both valves are actuated by the same camshaft

18. Most modern cars, instead of having separate camshafts for intake and exhaust, have a single camshaft with both intake and exhaust cams on it. In this case, intake and exhaust valves are usually placed side by side (Figure 6), instead of on opposite sides of the engine, or the valves are placed side by side in the cylinder head (Figure 7); the valves then being inverted

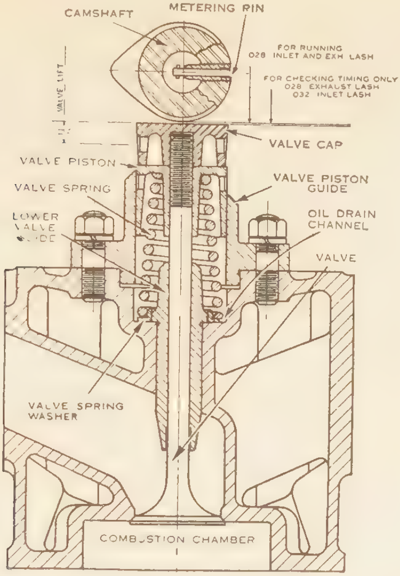
CAMSHAFT
METERING PIN
FOR RUNNING
028 INLET AND EXH LASH
FOR CHECKING TIMING ONLY
028 EXHAUST LASH
032 INLET LASH
VALVE LIFT
VALVE CAP
VALVE PISTON
VALVE PISTON GUIDE
VALVE SPRING
LOWER VALVE GUIDE
OIL DRAIN CHANNEL
VALVE
VALVE SPRING WASHER
COMBUSTION CHAMBER

Figure 8.—Section through Stutz valve mechanism

and opening downward. The type of engine shown in Figures 2 and 3 was chosen because it illustrates the valve action best. Figure 8 shows overhead valves actuated direct by an overhead camshaft, as in the Stutz car.

19. Figure 9 shows the Knight-sleeve-valve principle as used on the Stearns car. Two thin, cylindrical sleeves are placed between the piston and the cylinder wall, ports or slots in the sleeves registering with the intake and exhaust openings. The two sleeves are independently operated by connecting-rods attached to a small crankshaft which takes the place of the

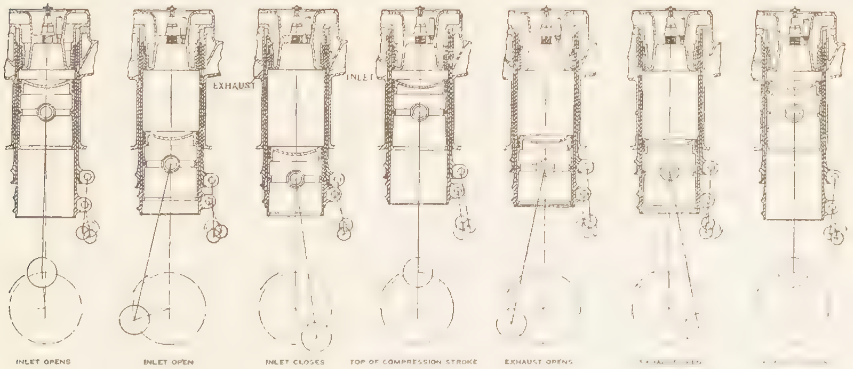
EXHAUST
INLET
INLET OPENS
INLET OPEN
INLET CLOSES
TOP OF COMPRESSION STROKE
EXHAUST OPENS

Figure 9.—Knight sleeve-valve engine

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EXPOSITION PARK

usual camshaft. It is driven at half crankshaft speed the same as a camshaft. The sleeves move in opposite directions and two sleeves are used to give quick opening and closing of the intake and exhaust ports. An examination of Figure 9 shows that the intake is open when the two intake slots are in line with the intake passage, and similarly for the exhaust.

FLYWHEEL

20. As only one piston stroke out of four is a power stroke, it is necessary to supply the rotating engine parts with sufficient momentum to carry them through the other three strokes—exhaust, suction, compression—without appreciable loss of speed. This need is supplied by the heavy cast-iron flywheel which is usually attached to the rear end of the crankshaft. It is convenient to call the flywheel a storehouse of power. During the explosion stroke, part of the downward force of the piston is used in propelling the car, while any force not needed for this work is stored up in the flywheel, the flywheel increasing speed slightly in proportion to the amount of power stored. After the power stroke come three strokes which not only generate no power, but instead require considerable power—the exhaust stroke takes a little, the suction stroke a little, while the compression stroke takes a much larger amount. The energy for these strokes must be supplied by the flywheel, and in the process it slows down slightly, although the total fluctuation throughout any four strokes may not be more than a fraction of a revolution per minute.

CYLINDERS

21. Instead of a single cylinder, 4 to 16 cylinders generally constitute an engine, to minimize vibration and provide a smooth, steady flow of power.

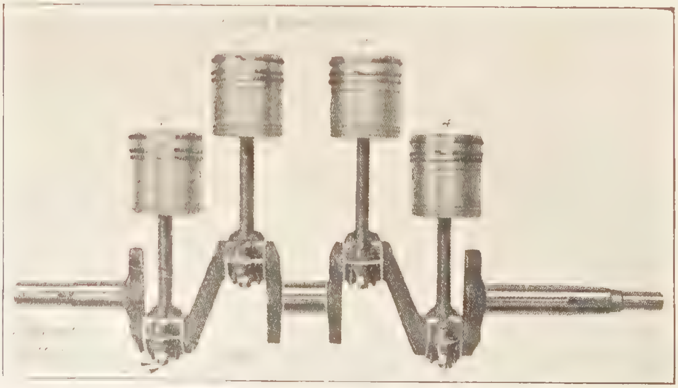


Figure 10—Typical crankshaft, pistons, and connecting rods for a 4-cylinder engine

And in making this preliminary survey of a typical car, for simplicity, the 4-cylinder type will be described first. The four cylinders are arranged in line, and each cylinder functions just like the single-cylinder engine just described. The crankshaft has four connecting-rods working on it, impelled by four pistons (Figure 10). The intake passage leading from the carburetor to the cylinders must have four branches, one for each cylinder, and likewise the exhaust pipe must have a connection to each cylinder (Figure 11).

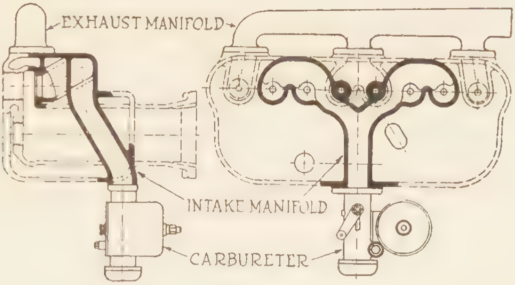


Figure 11.—Intake and exhaust passages. Right—a horizontal section through the cylinder; left—vertical section along center line of right view

22. One of the objections to the single-cylinder engine is that the rapid up-and-down motion of the piston and connecting-rod causes the engine to vibrate severely, but in the 4-cylinder engine (Figure 10), the motion of piston No. 1 is counterbalanced by the opposite motion of piston No. 2; likewise pistons No. 3 and 4 balance each other and the same holds true of connecting-rods No. 1 and 2, 3 and 4. Later, it will be shown that the balance of these parts in a 4-cylinder engine is not perfect, although it is good.

FIRING ORDER

23. By common consent, No. 1 cylinder is always the front one, regardless of how many cylinders the engine has, and the cylinders are always numbered from front to rear. Figure 10 shows that pistons No. 1 and 4 move up and down in unison, and so do pistons No. 2 and 3. Therefore, this crankshaft arrangement not only gives good balance, but it also gives equally spaced explosions—that is, an explosion occurs every half revolution of the engine crankshaft. In thinking of this statement, it should be remembered that each cylinder functions just as the single-cylinder engine first described, and in this single-cylinder engine an explosion stroke occurs every two revolutions, followed by exhaust, intake, and compression strokes, when the cycle of events is repeated indefinitely. Therefore, a 4-cylinder engine may be compared to 4 single-cylinder engines and a glance at the crank-

shaft (Figure 10), shows that as pistons No. 1 and 4 move together, the explosions in these two cylinders must either be arranged to take place at the same time or one revolution apart, and the same applies to cylinders No. 2 and 3. For the sake of equally spaced explosions, cylinder No. 4 should fire a whole revolution after No. 1, and No. 2 a whole revolution after No. 3, or conversely. This means that either cylinder No. 2 or 3 must fire half a revolution later than No. 1. If, when the engine is designed, it is decided that No. 2 is to fire half a revolution after No. 1, further study of Figure 10 will show that the next cylinder to fire will be No. 4 (half a revolution after No. 2 and a whole revolution after No. 1); finally No. 3 will fire half a revolution after No. 4, a whole revolution after No. 2, and 1½ revolutions after No. 1. Thus, the order in which the cylinders fire may be described as 1, 2, 4, 3. On the other hand, if No. 3 fires half a revolution after No. 1, the firing order will be 1, 3, 4, 2.

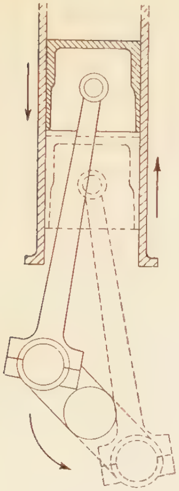


Figure 12.—Two pistons traveling at different velocities due to variation in angle of connecting-rods

24. Naturally, the order in which the cylinders work is determined by the arrangement of the cams on the camshaft or camshafts. If the camshaft is built to make the cylinders function in 1, 3, 4, 2 order, the only way that they might be made to function in 1, 2, 4, 3 order would be to make a new camshaft; lest there be any misunderstanding, one order is as good as the other and there is no reason why it should be necessary to change from one to the other.

25. The 4-cylinder engine is not in perfect balance although its balance is good enough to satisfy most people. The lack of perfect balance is simply

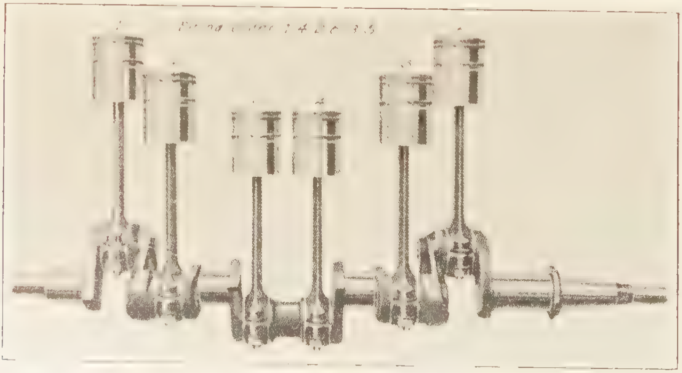


Figure 13.—Six cylinder crankshaft with pistons and connecting-rods attached

explained by referring to Figure 12, which represents pistons No. 1 and 2 or 3 and 4 in any 4-cylinder engine. Because of the difference in the angularity of the two connecting-rods it will be seen that the up piston, for the moment, is traveling much faster than the down piston, the vibration thus set up by pistons No. 1 and 2 is a wavy vertical motion and adds itself to the similar vibration produced by pistons No. 3 and 4. Light pistons and connecting-rods minimize this vibration, and it may be practically neutralized by the Lanchester balancer.

26. In the 6-cylinder engine an explosion occurs every two-thirds of a revolution, and the crankpins are spaced 120 degrees apart (Figure 13). Pistons No. 1 and 6 move together, also No. 2 and 5, and 3 and 4. The 6-cylinder engine may be thought of as two 3-cylinder engines combined, and is perfectly balanced, the action described in the previous paragraph being absent. There are many possible firing orders, as follows, although the first one is common:

1, 5, 3, 6, 2, 4
1, 2, 4, 6, 5, 3
1, 5, 4, 6, 2, 3
1, 2, 3, 6, 5, 4
1, 4, 2, 6, 3, 5
1, 3, 2, 6, 4, 5
1, 4, 5, 6, 3, 2
1, 3, 5, 6, 4, 2

ARRANGEMENT

27. With respect to 8-cylinder engines there are two methods of cylinder arrangement. One is known as the Vee eight and the other is variously described as the straight eight, line eight, or eight-in-line. The Vee eight consists of two sets of 4 cylinders set at an angle to each other, thus forming a Vee. Ordinarily, the angle is 90 degrees, but occasionally it is less as in the Lincoln car. The cylinders in a straight eight are arranged all in one row as in a six.

28. Counterbalance weights are added to the crankshaft of many modern cars to increase the smoothness of running and to reduce main bearing wear. Counterbalancing, however, is too technical a subject to permit further discussion here.

29. In the past, one of the causes of engine "roughness" has been torsional crankshaft vibration, therefore means have been taken in most modern engines to eliminate this defect. The forces that the connecting rods impose on the crankshaft makes it vibrate torsionally at certain engine speeds – that is, the front end of the crankshaft tends to "wind and unwind" at a rapid rate just as though it were made out of rubber, resulting in an objectionable vibration.

30. Four-cylinder crankshafts are so short that this effect may be ignored, but it can not be ignored in sixes or straight eights. The common remedy

is to place a vibration dampener on the front end of the crankshaft (Figure 14). This is a simple device consisting of a small split flywheel whose two halves are held apart by coil springs so that they press against two friction discs, which in turn press against collars fastened to the crankshaft. In other words, the only connection between the crankshaft and the split flywheel is a frictional one. Consequently, when the crankshaft begins to oscillate rotationally, the flywheel slips and thus prevents the oscillations from increasing to a point where they will be noticeable.

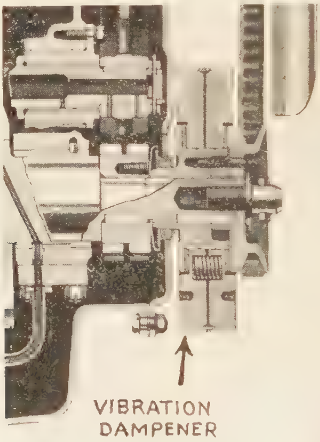


Figure 14.—Section of Packard "Eight," showing Lanchester vibration dampener

On Buick and Oakland sixes the same result is obtained in a different way: A pivoted weight is attached to the crankshaft between the first and second main bearings, being held in normal position by springs. When the crankshaft begins to vibrate rotationally, the weight begins to vibrate in the opposite direction; its vibrations cancel the incipient vibrations of the crankshaft, thus preventing the vibrations from becoming violent enough to be noticed.

Any crankshaft will vibrate torsionally at certain definite speeds, but a crankshaft of large diameter will have its periods of vibration at higher speeds than one of small diameter, other things being equal; for a given diameter of crankshaft, the lighter the shaft the higher are its vibration speeds. Thus it is evident that the shaft may be so designed that its first noticeable period of vibration is beyond the maximum speed of the car, consequently, in some of the later cars the vibration dampener has been eliminated by judicious crankshaft design.

31. Figure 15 shows a straight-eight engine removed from a car, turned upside down and the lower half of the crankcase or oil-pan removed. This crankshaft is mounted in 9 main bearings. The flywheel is bolted to a flange on the rear of the crankshaft and the chain which drives the camshaft is seen at the front. The upper halves of the main bearings are mounted in the crankcase and the lower halves of the main bearings are bolted in place. The portion of the crankshaft enclosed by each of these bearings is known as a main bearing journal. Likewise, the portion of the crankshaft enclosed by each connecting-rod bearing is called the connecting-rod bearing journal, or more likely, the *crankpin*.

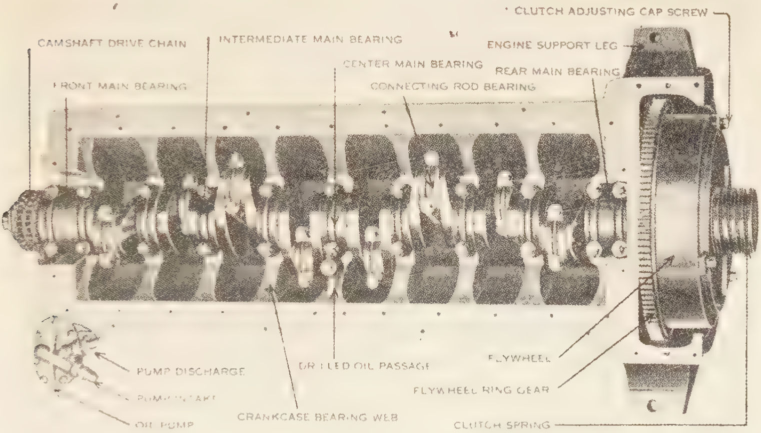

CLUTCH ADJUSTING CAP SCREW
CAMSHAFT DRIVE CHAIN
INTERMEDIATE MAIN BEARING
ENGINE SUPPORT LEG
CENTER MAIN BEARING
REAR MAIN BEARING
FRONT MAIN BEARING
CONNECTING ROD BEARING
PUMP DISCHARGE
DRILLED OIL PASSAGE
FLYWHEEL
PUMP INTAKE
FLYWHEEL RING GEAR
CRANKCASE BEARING WEB
OIL PUMP
CLUTCH SPRING

Figure 15.—Crankshaft, bearings, and other parts of an 8-cylinder engine

PISTON

32. As a rule, the piston (Figure 16), is supplied with three piston rings, to prevent undue leakage of gas and oil past the piston. It is not practicable to make the piston so tight a fit in the cylinder that leakage will be negligible, therefore rings are used to keep the leakage within bounds. The rings fit snugly in grooves in the piston and are designed so that they press out against the cylinder walls, thus largely preventing leakage. As a rule, the lower ring is a slotted design and the ring groove is equipped with oil drain holes. Thus the excess oil on the cylinder walls drains back through the ring slots and the drain holes and thus drops into the crankcase. As the function of this ring is primarily to control piston and cylinder lubrication, it is called an oil control ring, whereas the other rings on the piston are known as com-

pression rings, because their main function is to "hold compression"—in other words, to prevent leakage of gases from the combustion chamber.

33. Both the main and connecting-rod bearings are usually lined with a metal alloy called babbitt, somewhat harder than lead and somewhat softer than brass, silvery in color, and composed of tin, copper, and antimony.

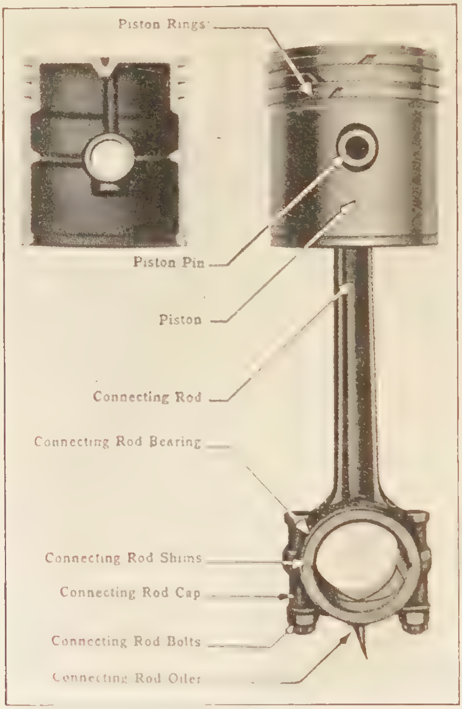

Piston Rings
Piston Pin
Piston
Connecting Rod
Connecting Rod Bearing
Connecting Rod Shims
Connecting Rod Cap
Connecting Rod Bolts
Connecting Rod Oiler

Figure 16.—Typical piston and connecting-rod with spoon or scupper on bottom of rod which dips into oil trough and thus splashes the oil around

LUBRICATION

34. The wearing surfaces of the engine must be lubricated continuously to minimize wear and friction. Friction, it should be remembered, generates heat, and unlubricated parts are likely to seize or melt. There are numerous methods of lubricating an automobile engine, and about the simplest is to place a crosswise trough under each connecting-rod, keep it filled with oil supplied by a pump from an oil reservoir, and attach a projection on the connecting rod so that it will dip into the trough (Figure 16). Once every revolution, therefore, each connecting-rod dips into the oil in its trough and splashes it in all directions. The result is that oil is splashed on all the interior parts of the engine, cylinder walls, pistons, connecting-rod and main

bearings, camshaft bearings, valve parts, and so forth. These troughs are supplied with oil through a pump which draws the lubricant from a reservoir just beneath the troughs. Excess oil overflowing from the troughs flows back to the reservoir, and splashed oil not used flows down the sides of the cylinders and the crankcase to the oil reservoir.

35. In addition to the oil screen which invariably surrounds the inlet to the pump, it is now rather general practice to place an external oil filter on the car; this device is filled with filtering material which is designed to remove every vestige of dirt from the oil. If the filter becomes clogged with dirt, a by-pass valve automatically allows oil to short-circuit around the filter; therefore, lubrication is maintained even when the filter is clogged. The filter unit should be changed every 10,000 miles; some men advise a change every 5,000 miles. The fact that oil is flowing through the by-pass indicates that a new filter unit is required.

36. Crankcase ventilation is a feature of many modern cars. A stream of air is allowed to pass through the crankcase to pick up any liquid fuel particles or any water which has leaked past the pistons, and prevent them from getting into the oil. Liquid fuel is objectionable in the oil because it thins the oil and reduces its ability to keep the wearing surfaces apart, thus increasing wear. Water in the oil (due to condensed steam which is one of the products of combustion) is objectionable because it forms an emulsion with the oil which, not only reduces the lubricating quality, but if enough water is present, it may change the oil into a semi-solid substance somewhat resembling liver which may clog the lubricating system and render it useless. Also, if sufficient water is present it may freeze and thus render the lubricating system inoperative. The elimination of water also minimizes corrosion in case there is sulphur in the fuel.

37. There are various ways of inducing a flow of air through the crankcase to obtain ventilation. The commonest method is to have an air opening at one side of the forward end of the crankcase and a pipe attached to the rear end on the opposite side; the forward motion of the car gives a suction action on the end of this pipe, with the result that air is drawn through the crankcase.

38. Another way to eliminate oil dilution by fuel and water particles is to use a special heating device through which the oil is passed. The heat drives off the fuel and the water, these two impurities being then sucked into the intake manifold.

COOLING

39. The heat generated in the cylinders would soon bring them to a white heat; hence the necessity for using air or water to keep the temperature down within reasonable limits. There are several reasons why the temperature must not be allowed to rise more than so high: (1) If the cylinder walls

become too hot the oil lubricating cylinders and pistons will vaporize, resulting in rapid wear, scoring (cutting of grooves or ridges), or seizure. (2) Metals expand in proportion to their temperature, but the excessive expansion which would occur in an uncooled engine would result in such distortion of pistons, cylinders, etc., that the parts would soon seize (stick). (3) The cylinder walls would soon become so hot that the incoming mixture of gasoline and air would be ignited by the cylinder walls long before the compression stroke was completed; thus little or no power would be developed. In fact, long before this, pre-ignition, as it is called, would probably be produced by particles of carbon in the cylinders becoming white hot because of the inability of the cylinder walls adjacent to keep them cool.

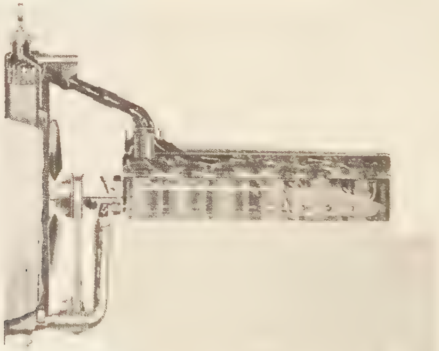


Figure 17.—A cooling system with pump circulation. The arrows indicate the flow. The water thermostat is at the point where the pipe to top of radiator joins the cylinder head

40. The typical engine is cooled by surrounding the cylinder walls, cylinder head, and valve chambers with water (Figure 17). The water flows continuously from the water jackets to the top of the radiator, while fresh water flows from the bottom of the radiator to the water jackets. The radiator is simply a device having a large surface exposed to the air so that the water in it will cool quickly. The water is gradually cooled as it moves from the top to the bottom. The temperature of the water at the top, for example, might be 150° F. and at the bottom 120° F. The radiator is made out of thin sheet metal, with numerous thin water passages running from top to bottom. These passages are separated from each other so that air may pass through the radiator. The forward motion of the car forces air through the radiator, and this air circulation is further increased by a fan, placed back of the radiator and driven by the engine. The water is kept in circulation

either by means of a pump driven from the engine, or thermo-syphon circulation is used; in the latter system the natural tendency of hot water to rise and cold water to fall is utilized. The warm water rises from the water jackets to the top of the radiator; as it cools it falls, and when it reaches the bottom it flows back up to the water jackets.

41. Oil dilution is a maximum when the engine is cold and usually negligible when the engine is hot. Also, engine lubrication is generally far from adequate when the engine is cold. Because of this dual situation it is generally believed that most engine wear occurs during the warming-up period, and obviously, the shorter this period the longer the wearing surfaces of the engine will last.

42. As one means toward warming the engine quickly it is becoming rather customary to reduce the effectiveness of the cooling system during the warming-up period, either by a radiator shutter which is closed manually or automatically, or by a thermostatic valve placed in the cooling system. The latter is mostly placed in the cylinder head, at the point where the water pipe carries the hot water to the top of the radiator. This valve remains closed until the water in the engine reaches about 150° F., and then it opens. Thus the engine, at the outset, is not asked to warm all the water in the cooling system but only the water in the water jackets; therefore, it warms up more rapidly that it would otherwise.

CARBURETION

43. To obtain perfect combustion 1 pound of gasoline must be vaporized and thoroughly mixed with 15 pounds of air. It is the function of the carburetor to supply such a mixture to the engine as required. No carburetor meets these requirements perfectly, but a carburetor must be considered satisfactory if it meets them well enough to obtain a reasonable development of power and economy of fuel. The carburetor must first be able to proportion the air and fuel, and then vaporize the fuel and thoroughly mix it with the air, whether the engine demand is heavy or light.

44. As shown in Figure 18, air flows up through the carburetor to the engine as indicated by the arrows. When the (damper) throttle is closed, little air gets to the engine, but when the throttle is wide open a maximum amount of air flows to the engine. As the air rushes by the gasoline nozzle, fuel is sucked out, vaporized, and mixed with the onrushing air. The air opening and the gasoline are so proportioned as to size that approximately 15 pounds of air flows through the carburetor for every pound of gasoline. Unfortunately, if the nozzle and air opening are correctly proportioned for small throttle openings, the mixture will be much too rich in gasoline as the throttle is opened, because it happens that gasoline flows out faster, as the throttle is opened, than does the air; therefore every automobile carburetor

must have some means for offsetting this situation. One simple method is to place a spring-closed air valve between the nozzle and the throttle to let in additional air as the throttle is opened. When the valve and spring are correctly proportioned and the spring correctly adjusted, the amount of air let in will approximately offset the extra fuel delivered by the nozzle. There are many other ways of compensating for this difference in the rate of flow between air and gasoline, and these are illustrated under Carburetors, paragraph 939.

45. The gasoline level in the carburetor is maintained just below the top of the nozzle or jet by means of a float-controlled needle valve. A study of Figure 18 shows that as soon as the engine begins to suck gasoline out of the nozzle the gasoline level in the float chamber begins to fall. Thus the float falls and this raises the needle valve which controls the flow of fuel into the float chamber and allows more fuel to enter. The faster the fuel is drawn from the nozzle the more the fuel level falls, and the wider the needle valve opens. On the other hand, the fuel can not flow out of the nozzle except when induced by the engine suction, because the float valve closes before the fuel level can rise to this height. This discussion, of course, assumes that the mechanism is properly designed and in good order. To provide a rich mixture for easy starting it is usual to employ a choke damper in the air intake to the carburetor; closing this damper increases the air suction on the gasoline and thus causes more fuel to flow out. However, it must be kept in mind that there are other methods of obtaining the same result.

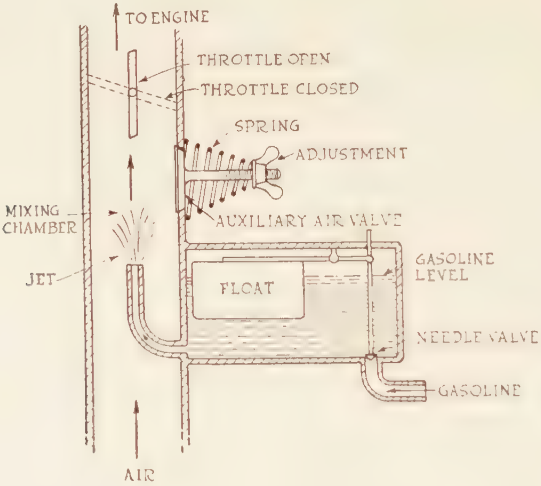


Figure 18.—Principle of the carburetor. The usual choke mechanism consists of a damper valve like the throttle, but placed below the jet

FUEL FEED

46. Gasoline is generally delivered from the gasoline tank to the float chamber either by action of gravity, air pressure, pump, or engine suction. If gravity is employed the tank must be placed higher than the carburetor. Where engine suction is used the Stewart vacuum system is largely employed. It consists of a device in which engine suction is used to draw fuel from the gasoline tank to the vacuum tank and deliver it from the vacuum tank to the carburetor by gravity. On the typical car, gasoline is drawn from the tank at the rear to the vacuum tank, and flows from this tank, by gravity, to the carburetor. The A C fuel pump, described in paragraph 902 has recently come into use on several cars.

IGNITION SYSTEM

47. It is necessary to approach the study of the electrical system with confidence. There is nothing difficult about electricity or its application to the automobile. The ignition system, for example, is no more complicated and just as readily understandable as the plumbing system in the average residence, which is not difficult to follow.

48. The purpose of the ignition system is to ignite the explosive mixture in each cylinder at the right instant, which is while the piston is near the top of its compression stroke, and just a moment before the piston starts on its explosion stroke. The mixture is ignited by an electric spark jumping be-

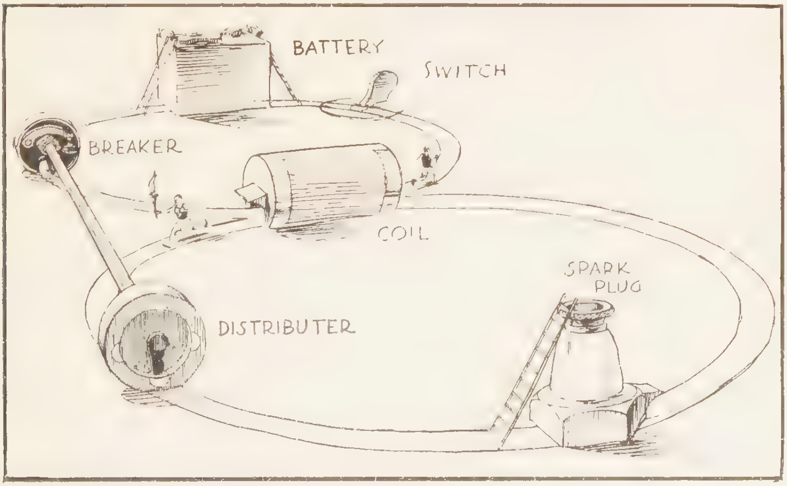


Figure 19.—An ignition system may be represented by two circles, the upper being the low-tension circuit and the lower the high-tension circuit. The path of the current in both circuits is indicated by the runners

tween the points of a spark-plug, which are approximately 1/32 inch apart. The function of the ignition system is to produce and deliver the spark at the plug points at just the right moment.

49. The electric current used for ignition must have a pressure of several thousand volts to jump the gap at the spark-plug points, just the same as high pressure would be required to force a large quantity of air through a small hole. Unfortunately, the only convenient sources of current supply give a low pressure, usually about 6 volts. Therefore it is necessary to have a device for changing this low-pressure current into a high-pressure current; the device used is an induction coil, commonly called a spark coil.

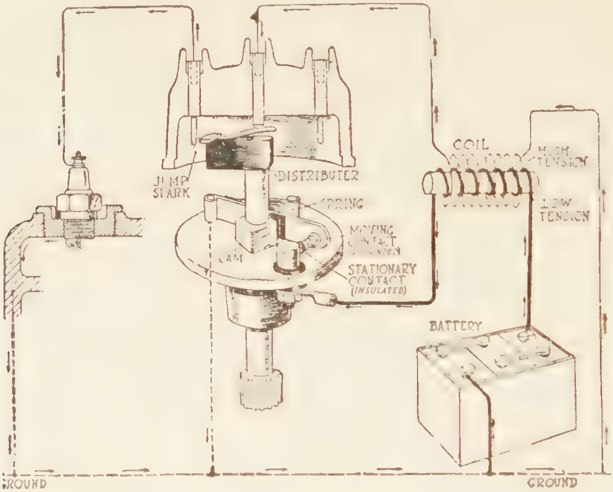


Figure 20.—Diagram of typical battery ignition system

50. For those who are mystified by electrical matters it is helpful to think of the wires as paths (Figure 19), while runners bearing torches represent the ignition current. The upper circle shows the low-tension (low-pressure) circuit, and the lower circle the high tension circuit. When the ignition switch is closed, assume that a runner bearing a lighted torch is all ready to dash out of the battery just as soon as the breaker points separate; that is the signal. The instant the points separate he dashes to the coil where he hands his torch to another runner who traverses the high tension circuit. When the latter reaches the distributor, a rotating arm (called the distributor brush or rotor arm) directs him to one of the four paths leading out to the four spark-plugs, one for each cylinder. Without loss of time the runner proceeds to the spark plug points where he drops his torch, ignites the mixture, and then dashes back to the coil ready to receive the next torch. In returning from spark plug to coil he goes through the engine and the car frame, these parts

taking the place of wires. Likewise, the runner in the low-tension circuit passes through the engine and frame in going from the breaker back to the battery. It is important to remember that the separation of the breaker points is the signal for the production of the spark, while the purpose of the distributor is to switch or direct the spark to the right cylinder. The breaker mechanism and distributor brush are generally driven from the same shaft, and the two are called the ignition unit.

51. Figure 20 shows a close-up of a breaker and distributor mechanism. The central shaft is positively driven by a gear at half the engine speed, and the cam is so set that at the instant when it forces the breaker points apart one of the cylinders is just ready to have an explosion, while the distributor mechanism sees to it that this spark is directed to the cylinder that needs it. The distributor cap is made of non-metallic material which acts as an insulator, and usually it is located above the breaker mechanism. On a 4-cylinder engine there are four metal segments set in the cap, and each segment is connected by wire to a spark-plug. The distributor brush is mounted on the end of the shaft which drives the breaker. The high-tension current comes from the coil down a central wire through the distributor cap and thence to the distributor brush, whence the current is switched to one of the metal segments and then goes to the spark-plug. The distributor brush is carefully set so that it is always on a segment when the breaker points separate.

SPARK-PLUG

52. Figure 21 shows a spark-plug split down through the center. One of the spark-plug points is attached to the outside shell and the other comes

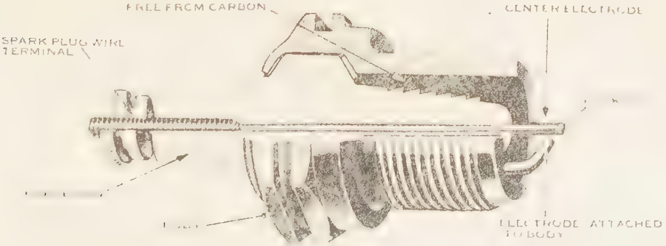


Figure 21.—Construction of a spark-plug

down through the center. This center electrode, as it is called, is carefully insulated from the metal shell by a heavy porcelain piece. The spark-plug wire running from the distributor is attached to the top of the center elec trode; it is considered that the high-tension current comes down through the center electrode, and jumps the gap at the points, whence it returns to the coil through the spark-plug shell, engine, and frame.

SPARK ADVANCE

53. To produce maximum power and economy, the spark must ignite the mixture in the cylinder at exactly the right instant, and this instant is a little before the piston starts down on the explosion stroke, so that the maximum pressure may be exerted on the piston at the very beginning of its power stroke. The interval between the separation of the breaker points (which is the signal for the spark to occur) and development of maximum pressure in the cylinder, is a very small one. Yet, to obtain maximum pressure at the very beginning of the explosion stroke, when the engine is running fast it is necessary to cause the breaker points to separate sooner; the faster the engine runs the sooner they must separate. In other words, as the engine speed increases the spark must be *advanced*. Ordinarily, this is done by rotating the ignition unit through a small angle, in the opposite direction to the rotation of the breaker shaft. The more the unit is advanced the *earlier* the spark occurs. Movement of the spark lever on the steering wheel advances or retards the ignition unit and therefore the sparks which are produced by it.

54. The ignition unit may be advanced manually by operating the spark-advance lever; automatically by centrifugal weights built into the unit, which advance the ignition as the speed increases; and both these systems may be used together, in which case the advance produced by the spark lever is added to whatever is produced by the centrifugal mechanism. In other words, if the maximum advance of each were 20 degrees, the total maximum advance would be 40 degrees.

55. A few cars are equipped with dual ignition—that is, they have two spark-plugs per cylinder placed at opposite sides. Years ago this was popular on some of the higher grade cars for the sake of greater reliability, the thought being that if the ignition system supplying one set of spark-plugs failed to function the other would bring the car home. However, the recent increase in popularity of dual ignition is due to an entirely different reason. On some engines at least dual ignition gives more power and the power increase is partly if not wholly due to the fact that dual ignition permits the use of higher compression, and higher compression in turn gives more power.

56. Dual ignition systems are similar in principle to single ignition systems. Ordinarily, one set of spark-plugs is supplied through one coil and the other set through a second coil. As a rule, the distributor has double the number of contacts ordinarily employed. In other words, in a 6-cylinder engine there are 12 contacts instead of 6, and 12 high-tension wires running to

12 spark-plugs, instead of 6 high-tension wires running to 6 spark-plugs, and there are two breaker mechanisms instead of one, one breaker for each coil, both breakers being operated ordinarily from the same cam.

STARTING SYSTEM

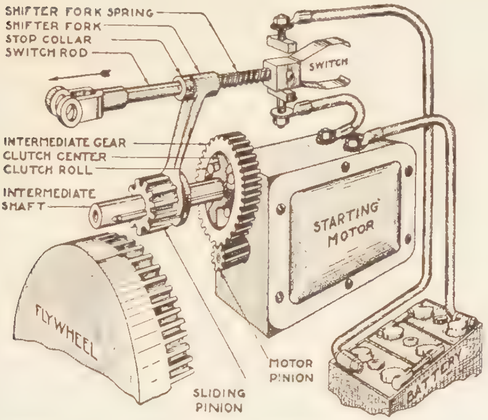

SHIFTER FORK SPRING
SHIFTER FORK
STOP COLLAR
SWITCH ROD
SWITCH
INTERMEDIATE GEAR
CLUTCH CENTER
CLUTCH ROLL
INTERMEDIATE SHAFT
STARTING MOTOR
FLYWHEEL
MOTOR PINION
SLIDING PINION
BATTERY

Figure 22.—The starting motor is connected to the battery with heavy cables and the circuit is closed by a switch, whose operation (in this type) also meshes the starter gear with the flywheel

57. The usual starting system (Figure 22), consists of a starting switch (pedal operated), an electric starting motor, a storage battery and a heavy wire running from battery to switch to starting motor. When the switch is closed a current flows from the battery through the motor, and the motor rotates and cranks the engine, while current returns from motor to battery by way of the engine and frame.

LIGHTING SYSTEM

58. The easiest way to explain the lighting circuit is to call the generator an electrical *factory* (Figure 23), the battery a storehouse, the lights, ignition unit and starting motor, *consumers* (but for simplicity only the

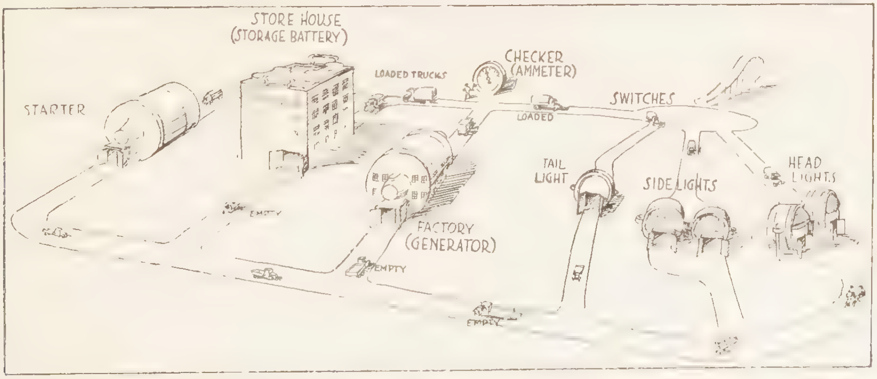

STORE HOUSE (STORAGE BATTERY)
LOADED TRUCKS
CHECKER (AMMETER)
STARTER
LOADED
SWITCHES
TAIL LIGHT
SIDE LIGHTS
HEAD LIGHTS
EMPTY
FACTORY (GENERATOR)
EMPTY
EMPTY

Figure 23.--The simplest way to explain the starting and lighting system is to call the generator an electrical *factory*, the battery a *storehouse*, the starter and lights, *consumers*, and the wires, *roads* lights are shown), and the wires, *roads*. Further, it may be imagined that while the engine is running there is a steady stream of motor trucks proceeding from the factory, each with a load of electricity. Shortly after leaving the factory the road branches to right and left. As many trucks as required, swing to the right to supply lights and ignition, while the remaining trucks deposit the surplus in the storehouse. The ammeter is a device which indicates the rate at which current is being put into or taken out of the battery.

59. If there are no lights on there is only the ignition system to be supplied and all the excess goes to the battery. On the other hand, if all the lights are on, they may demand nearly all the current produced by the factory and there will be little surplus to put into the storehouse. Mostly the empty trucks return to the generator by a common highway, as shown, through the metal frame of the car. This arrangement saves wiring and makes for simplicity.

60. Whenever the engine stops the factory is forced to shut down and then if current is wanted for lighting, ignition, or starting, it must be withdrawn from the battery. The lighting switches may be compared to drawbridges. Loads of electricity can be delivered to the lamps and ignition when the bridges are closed.

61. A complete starting, lighting and ignition system is illustrated in Figure 24, and two detail views of a modern engine are shown in Figures 25 and 26.

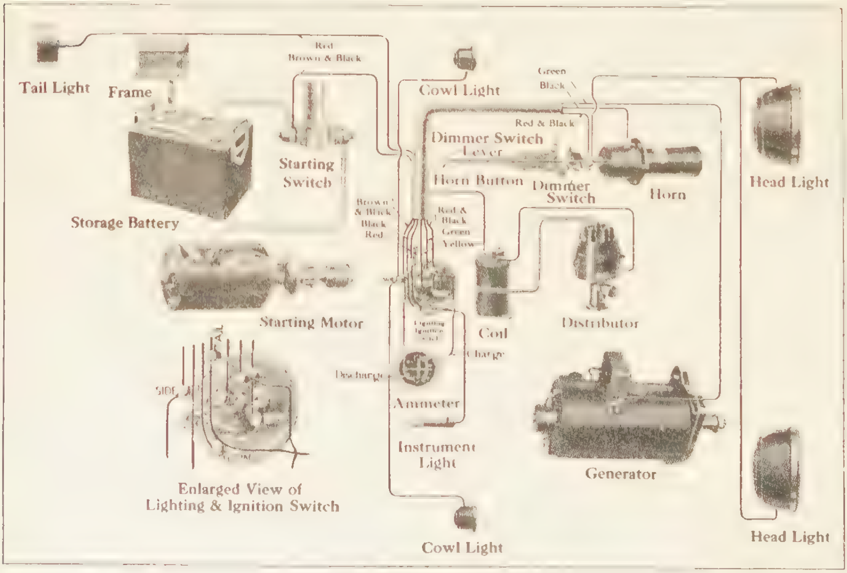

Tail Light
Frame
Red
Brown & Black
Cowl Light
Green
Black
Red & Black
Dimmer Switch
Lever
Starting
Switch
Horn Button
Dimmer
Switch
Horn
Head Light
Storage Battery
Brown
& Black
Black
Red
Red &
Black
Green
Yellow
Starting Motor
Coil
Distributor
Charge
Discharge
Ammeter
TAIL
SIDE
Instrument
Light
Generator
Enlarged View of
Lighting & Ignition Switch
Cowl Light
Head Light

Figure 24.—Typical starting, lighting, and igniting system

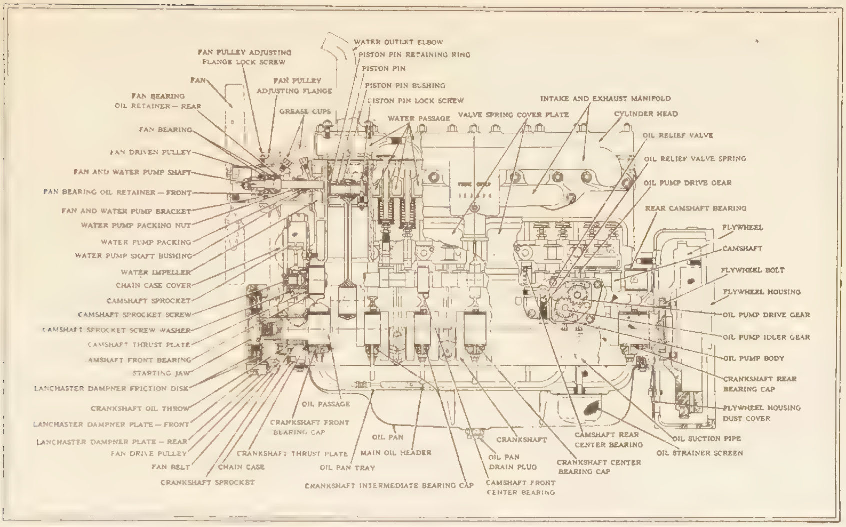

WATER OUTLET ELBOW
PISTON PIN RETAINING RING
PISTON PIN
PISTON PIN BUSHING
PISTON PIN LOCK SCREW
FAN PULLEY ADJUSTING FLANGE LOCK SCREW
FAN
FAN PULLEY ADJUSTING FLANGE
FAN BEARING OIL RETAINER — REAR
GREASE CUPS
WATER PASSAGE
VALVE SPRING COVER PLATE
INTAKE AND EXHAUST MANIFOLD
CYLINDER HEAD
OIL RELIEF VALVE
OIL RELIEF VALVE SPRING
OIL PUMP DRIVE GEAR
REAR CAMSHAFT BEARING
FAN BEARING
FAN DRIVEN PULLEY
FAN AND WATER PUMP SHAFT
FAN BEARING OIL RETAINER — FRONT
FAN AND WATER PUMP BRACKET
WATER PUMP PACKING NUT
WATER PUMP PACKING
WATER PUMP SHAFT BUSHING
WATER IMPELLER
CHAIN CASE COVER
CAMSHAFT SPROCKET
CAMSHAFT SPROCKET SCREW
CAMSHAFT SPROCKET SCREW WASHER
CAMSHAFT THRUST PLATE
CAMSHAFT FRONT BEARING
STARTING JAW
LANCHASTER DAMPNER FRICTION DISK
CRANKSHAFT OIL THROW
LANCHASTER DAMPNER PLATE — FRONT
LANCHASTER DAMPNER PLATE — REAR
FAN DRIVE PULLEY
FAN BELT
CHAIN CASE
CRANKSHAFT SPROCKET
FLYWHEEL
CAMSHAFT
FLYWHEEL BOLT
FLYWHEEL HOUSING
OIL PUMP DRIVE GEAR
OIL PUMP IDLER GEAR
OIL PUMP BODY
CRANKSHAFT REAR BEARING CAP
FLYWHEEL HOUSING DUST COVER
OIL PASSAGE
CRANKSHAFT FRONT BEARING CAP
OIL PAN
CRANKSHAFT
CAMSHAFT REAR CENTER BEARING
OIL SUCTION PIPE
OIL STRAINER SCREEN
CRANKSHAFT THRUST PLATE
MAIN OIL HEADER
OIL PAN DRAIN PLUG
CRANKSHAFT CENTER BEARING CAP
OIL PAN TRAY
CRANKSHAFT INTERMEDIATE BEARING CAP
CAMSHAFT FRONT CENTER BEARING

Figure 25.—Side section view of Peerless 6-80 engine

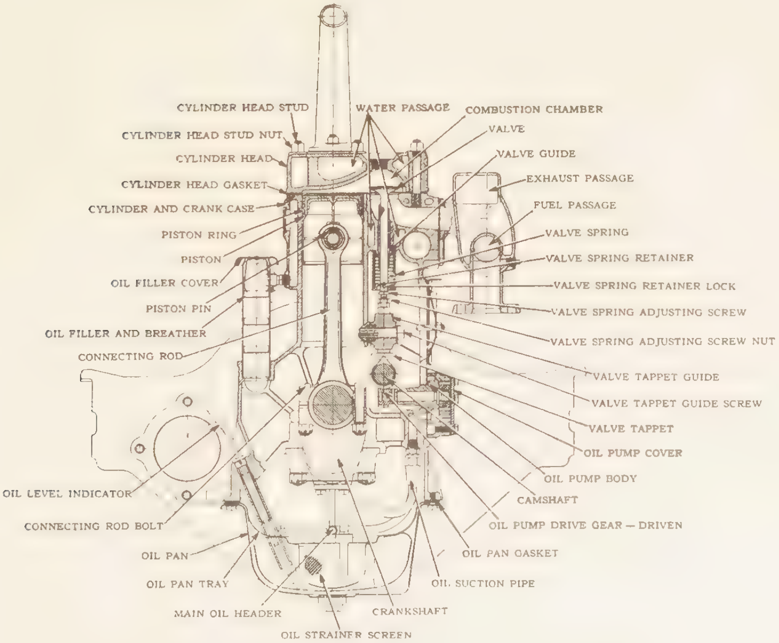

CYLINDER HEAD STUD
WATER PASSAGE
COMBUSTION CHAMBER
CYLINDER HEAD STUD NUT
VALVE
CYLINDER HEAD
VALVE GUIDE
EXHAUST PASSAGE
CYLINDER HEAD GASKET
CYLINDER AND CRANK CASE
FUEL PASSAGE
PISTON RING
VALVE SPRING
PISTON
VALVE SPRING RETAINER
OIL FILLER COVER
VALVE SPRING RETAINER LOCK
PISTON PIN
VALVE SPRING ADJUSTING SCREW
OIL FILLER AND BREATHER
VALVE SPRING ADJUSTING SCREW NUT
CONNECTING ROD
VALVE TAPPET GUIDE
VALVE TAPPET GUIDE SCREW
VALVE TAPPET
OIL PUMP COVER
OIL PUMP BODY
OIL LEVEL INDICATOR
CAMSHAFT
CONNECTING ROD BOLT
OIL PUMP DRIVE GEAR — DRIVEN
OIL PAN
OIL PAN GASKET
OIL PAN TRAY
OIL SUCTION PIPE
MAIN OIL HEADER
CRANKSHAFT
OIL STRAINER SCREEN

Figure 26.—Front section view of Peerless 6-80 engine

THE CLUTCH

62. The purpose of the clutch, as previously mentioned, is to connect and disconnect the engine with the driving mechanism. The simplest type to describe is the cone clutch (Figure 27). A cone 12 or 15 inches in diameter fits snugly into a conical recess in the flywheel. The flywheel, of course, is connected to the end of the crankshaft, and the cone is attached to a short shaft going to the transmission. A powerful spring forces the cone tightly into the flywheel so that the crankshaft and the transmission shaft revolve as though they were bolted together. The clutch is disconnected by pressing down on the pedal, which pulls the cone a quarter of an inch or so away from the flywheel. At this time the engine runs free and can transmit no power to the car. The instant the foot is removed from the pedal, the spring forces the cone back into the flywheel, and the cone revolves with the flywheel again.

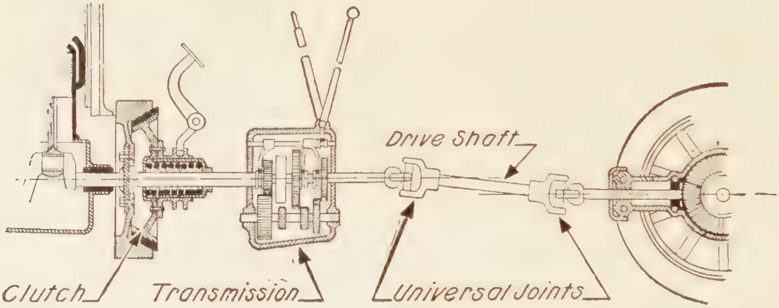
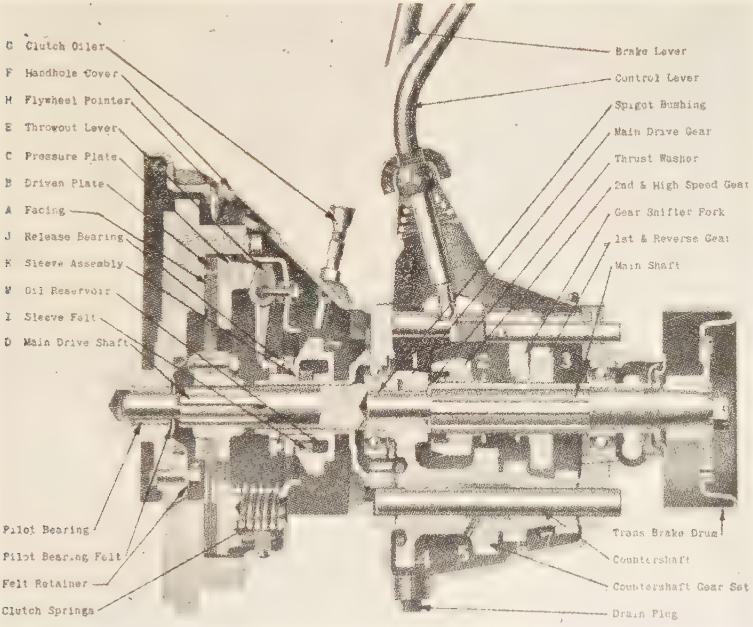


Figure 27.—Diagram of cone clutch, transmission, and rear axle

THE TRANSMISSION

63. The method of using the clutch in driving the car can not be clearly understood until a general idea of the transmission and rear axle is obtained, therefore these parts will be described before completing the explanation of the clutch. Figure 27 shows the whole revolving mechanism from crankshaft to rear wheels. On high gear the drive through the transmission is direct that is, the main shaft and the clutch shaft revolve as one. The two are usually coupled together by the meshing of an internal gear fastened solidly to the rear of the clutch shaft with a mating external gear, slidably attached to the front end of the main shaft (Figure 28). The main shaft and the clutch shaft are kept exactly in line because the end of the clutch shaft has a small bearing into which the end of the main shaft fits.

64. Gears *1* and *4,* Figure 28, are always in mesh, therefore the countershaft revolves whenever the clutch shaft revolves. Gears *2* and *3* are built so that they can slide along the main shaft—hence the name *sliding-gear* transmission. When gear *2* is moved all the way forward it meshes with gear *1,* and direct drive or high gear is obtained. When gear *2* is moved into mesh with gear *5*, second or intermediate speed is obtained, and the engine power passes from the clutch shaft to the countershaft through gears *1* and *4,* and thence to the main shaft through gears *5* and *2*. From *2* the power passes back to the driveshaft and the rear wheels. The reader who is unfamiliar with gearing may wonder just what is accomplished by this gear arrangement, and this is the explanation: Gear *4* is larger than gear *1*. Therefore gear *4* must rotate more slowly than gear one. In other words, the countershaft rotates more slowly than the main shaft. Likewise, gear *5* is smaller than gear *2*, therefore the main shaft must rotate more slowly than the countershaft. Therefore the main shaft must rotate much more slowly than the clutch shaft (on second gear). On high gear, it will be remembered, the clutch shaft and the main shaft run at the same speed, whereas on second gear the main shaft runs much slower than the clutch shaft, or to say it another way, the clutch shaft runs much faster than the main shaft. In other



G Clutch Oiler
F Handhole Cover
H Flywheel Pointer
E Throwout Lever
C Pressure Plate
B Driven Plate
A Facing
J Release Bearing
K Sleeve Assembly
M Oil Reservoir
I Sleeve Felt
D Main Drive Shaft
Pilot Bearing
Pilot Bearing Felt
Felt Retainer
Clutch Springs
Brake Lever
Control Lever
Spigot Bushing
Main Drive Gear
Thrust Washer
2nd & High Speed Gear
Gear Shifter Fork
1st & Reverse Gear
Main Shaft
Trans Brake Drum
Countershaft
Countershaft Gear Set
Drain Plug

Figure 28.—A 3 speed sliding gear transmission and single-plate clutch in Jordan car

words, for a given car speed the engine runs much faster on second gear than it does on high gear, and of course, the faster the engine runs the more power it develops (within certain limits). This means that the car will climb steeper hills on second gear than on high gear.

65. On low gear (first gear) the path of the power is through gears *1, 4, 6, 3.* Gear *6* is smaller than gear *5,* while gear *3* is larger than *2,* the obvious result being that the main shaft revolves much more slowly with gears *3* and *6* in engagement than it does with gears *2* and *5* in engagement. The consequence is that the main shaft runs much slower on low gear than on second, or conversely, the clutch shaft runs much faster (as compared to the main shaft) on low gear than on second. And the result is that the engine develops its maximum power at a moderate car speed, and thus the car is capable of negotiating any road or hill, provided that the wheels do not slip.

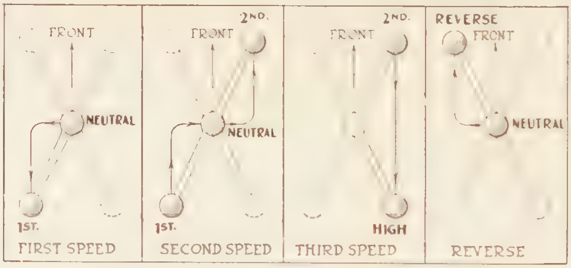


Figure 29.—Diagram of how various gears in the transmission are engaged

66. On reverse gear the power passes through gears *1, 4, 6, 7, 3.* Gear *7* is a small one mounted on a special shaft off to one side and it meshes both with *3* and *6.* On second gear and low gear, the power passes through four gears, while on reverse it passes through five gears, and it is this extra gear which reverses the motion. When power passes through four gears arranged as illustrated the *driven* shaft (main shaft) rotates in the same direction as the *driving* shaft (clutch shaft) but when the power passes through a train of five gears, the driven shaft rotates in a direction opposite to the driving shaft.

67. The meshing of these various gears to give high, intermediate, low, and reverse is accomplished by the gear-shift lever. The hubs of gears *2* and *3* are provided with a deep groove called a collar, into which a forked rod fits. Each of these rods is mounted on a sliding shaft (shifting shaft) which is actuated by the gear-shift lever. When one rod is moved forward it meshes high gear, when backward, second gear. Moving the other rod forward engages low gear and backward, reverse. The gear-shift lever can be moved forward or backward or to either side because it is mounted or pivoted in a ball-and-socket joint. The lower end of the lever fits into a

notch on either one of the two shifting shafts, so that movement of the lever shifts the gears. When the lever arm stands straight up and down, and the two notches are in line, no gears are engaged, in other words, the lever is in neutral. The positions of the lever are illustrated by Figure 29.

68. It should now be clear that there are two ways of disconnecting the power, by disengaging the clutch or by bringing the gear lever to neutral position. Conversely, after the engine has been started, two things are required to connect the engine to the rear wheels: The clutch must be in engagement and the gear-shift lever must be moved to the position which gives low, second, high, or reverse. The clutch, of course, is held in engagement continuously by its spring, and is disengaged only during the time that the clutch pedal is depressed by the foot. Some readers may wonder why it is not possible to dispense with the clutch and start the car simply by shifting to low gear, for example. However, if this were done the car would start with a tremendous jerk, the engine would stall, or more likely, the extremely sudden connection of the engine with the rear wheels would break some part of the driving mechanism, probably the gear teeth. Therefore, gears should only be brought into mesh when the clutch is disengaged, and the car should be started by letting the clutch in slowly. Likewise in shifting from one gear to another, the clutch must be disengaged.

69. The cone clutch (Figure 27), is faced with soft leather, or asbestos fabric riveted in place to provide a smooth engagement, combined with adequate gripping power, and the latter requirement means that the clutch must be able to transmit the full power of the engine without slipping. Various types of clutches are described in the chapter on clutches, paragraph 1801.

MESH GEAR

70. New types of transmission are now being used. One of these, employed on the 1929-1930 Cadillac and LaSalle, is the Synchro-Mesh transmission which permits a silent shift under all conditions whenever engaging second or high (Figure 30). In other respects the transmission is a 3-speed sliding-gear type.

71. When starting from rest, low is engaged as usual without any trouble because the car is not in motion; shifting from low to second is silently accomplished because the synchro-mechanism acts on the second gear; similarly, shifting to high is silently done; likewise the shift from high to second is made without a sound. The mechanism is particularly appreciated when it is necessary to go around another car, especially in traffic, because it invites shifting whereas the operator is inclined to struggle by in high with the conventional gear shift.

72. Reading from left to right, Figure 31 shows how the sliding coupling moves from neutral to engage intermediate or second gear, being actuated by

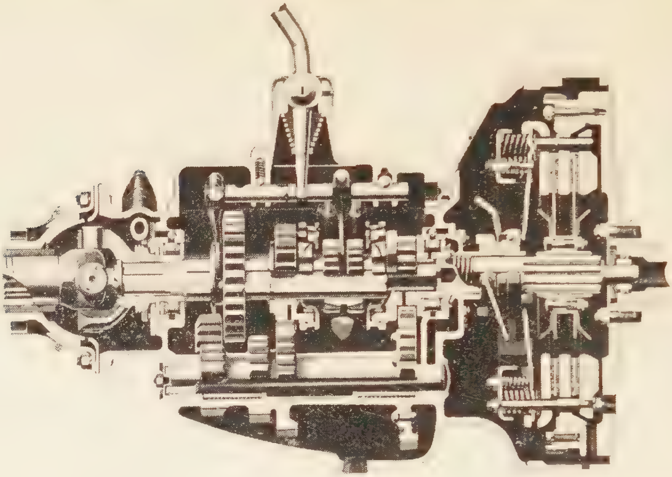


Figure 30.—Section through Cadillac-La Salle synchro-mesh transmission

the gear-shift lever working through the usual shifter shaft and shifter fork. Main shaft second gear is in constant mesh with its mate on the countershaft and when not in use rotates freely on a bronze bushing splined to the main shaft. To engage second gear, the sliding coupling which is splined to the main shaft is moved to the left until it meshes with the internal gear, which is integral with main shaft second gear, thus locking second gear to the main shaft. High gear is engaged in the conventional manner by moving the sliding coupling to the right until it meshes with the internal gear on the clutch shaft.

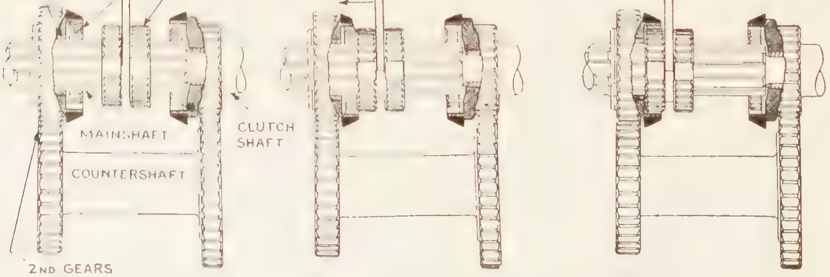

GEARSHIFT LEVER
SHIFTER SHAFT
INTERNAL GEAR
BRONZE BUSHING
SLIDING COUPLING
MAINSHAFT
CLUTCH SHAFT
COUNTERSHAFT
2ND GEARS

Figure 31.—Method of engaging high gear on Cadillac-La Salle transmission

73. It is obvious that in any sliding-gear transmission, silent meshing can result only by bringing the meshing teeth to exactly the same speed. In the Cadillac-LaSalle transmission this is done by individual metal-to-metal cone clutches on the main shaft engaged temporarily to bring the teeth of the high or second internal gear to the speed of the teeth on the sliding coupling splined to the main shaft.

74. Reading from left to right, Figure 32 shows the action of the cone clutch in meshing second gear. The three positions of the clutch mechanism correspond exactly with the three positions of the shifter gear (Figure 31). Shifter gear and cone clutch are shown separately for clearness.

75. It should be noted that with plate clutch disengaged and gear shift in neutral, main shaft second gear, and the countershaft assembly and the plate-clutch shaft assembly rotate freely as a single unit, because the main shaft intermediate gear is free to rotate on its bronze bushing. (To avoid confusion, the main clutch in the flywheel is called a plate clutch.) Therefore, when second gear cone clutch is engaged it is able to alter the speed of this whole assembly to the point where main shaft second gear is rotating at main shaft speed, thus permitting silent meshing of the shifter gear.

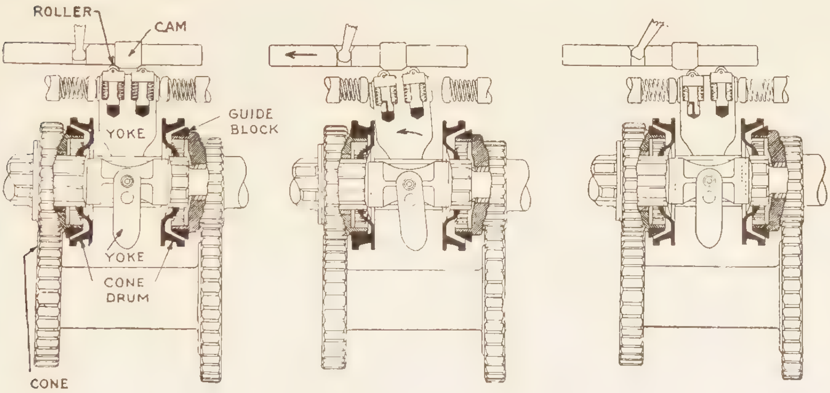


Figure 32.—Method of synchronizing engagement for silent shifting in Cadillac La Salle car

76. Similarly, when high gear cone clutch is engaged it alters the speed of the whole assembly to the point where high internal gear is rotating at main shaft speed. After the gears are meshed, the cone clutch is disengaged automatically and moves back to neutral.

77. For simplicity, Figure 31 shows the sliding coupling but not the cone clutches and their operating mechanism, while Figure 32 shows the cone clutches and their operating mechanism but not the sliding coupling. Actually, these units are combined as shown in the sectional view (Figure 30).

while the whole main shaft mechanism except the main shaft itself is shown in Figure 33. Note that the cone drums are carried on three spokes which are splined to the main shaft, while the sliding coupling has its teeth cut away so that it can slide between the spokes to mesh with the internal gear which is at the other side of the cone drum.

78. Figure 32 also shows the mechanism which moves the cone clutch in and out of engagement. The clutch is moved into engagement by a cam on the shifter shaft which acts against a roller that rocks a yoke pivoted below its middle to the sides of the transmission case (also see Figure 33), thus moving the guide block (Figures 32 and 33) which moves the cone drum.

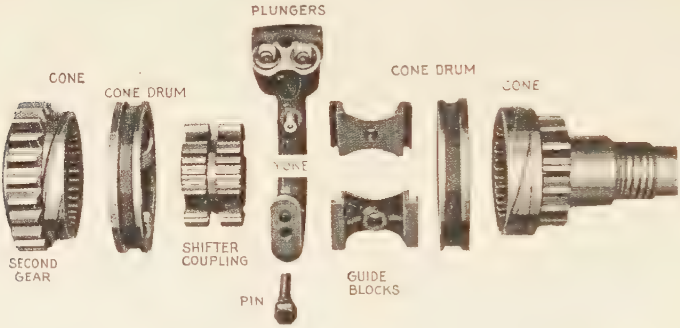


Figure 33.—Details of Cadillac-La Salle synchro-mesh mechanism

OPERATION OF MESH

79. Reading from left to right (Figure 32), the first illustration shows the mechanism in neutral; the second shows the clutch mechanism moved to the left, with the clutch fully engaged, and the sliding coupling just beginning to mesh (Figure 31). The third pair of pictures shows the sliding coupling fully meshed, while the yoke and the cone clutch drum have been forced back to neutral under the action of the spring to the left of the yoke. Cone-clutch action in high is similar.

80. The movement of the roller plunger is hydraulically controlled to time properly the period of clutch engagement. It is apparent that time is required to bring the internal-gear assembly up to main shaft speed. Actually, the time is so short as to be negligible from the operator's standpoint; nevertheless, time is required. If the roller plunger were backed only by the spring shown in Figure 32, the roller would slip back over the flat part of the cam so quickly that the cone clutch would not remain in engagement long enough to bring the assembly to main shaft speed. To delay this action (to increase the period of cone-clutch engagement) the base of the plunger butts against a piston which works in an oil chamber (Figure 34), and the down-

ward speed of the plunger and piston is limited to the speed at which oil will flow from the oil chamber to the chamber inside the plunger, as indicated by the arrows. In very cold weather, when the transmission oil is thick, the downward speed of the plunger is controlled by the opening of the spring-closed conical relief valve which provides an enlarged passage for the thick oil. The spring on this valve, however, is strong enough to prevent the valve opening when the oil is thin. In either case the retarding effect of the oil holds the clutch in engagement long enough to bring the assembly to main shaft speed. The mechanism is supplied with oil thrown from the transmission gears.

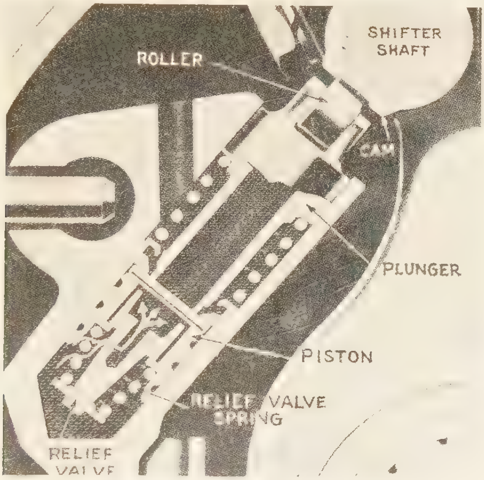


Figure 34.—Oil-plunger mechanism in Cadillac-La Salle transmission

81. Figure 35 shows the 4-speed transmission used on Graham-Paige models (on January 1, 1930, the name Graham replaced Graham-Paige) in which fourth speed is direct and third speed is through silent internal gears. Fourth speed is used for fast smooth traveling along the level and third speed for steep hills. The flow of power on first, second, third, and fourth speeds is indicated by the arrows and the numerals, *1, 2, 3* and *4*. On third speed two pairs of internal-external gears are used which are practically inaudible. Separate arrows indicate how the gears are moved to obtain the various speeds. Although this transmission has four speeds, it may still be described as a standard shift, because second, third, fourth, and reverse occupy the same positions as first, second, third, and reverse in the standard 3-speed transmission. First speed is used only in emergency, as when pulling out of deep sand or mud, and is at the left and to the rear

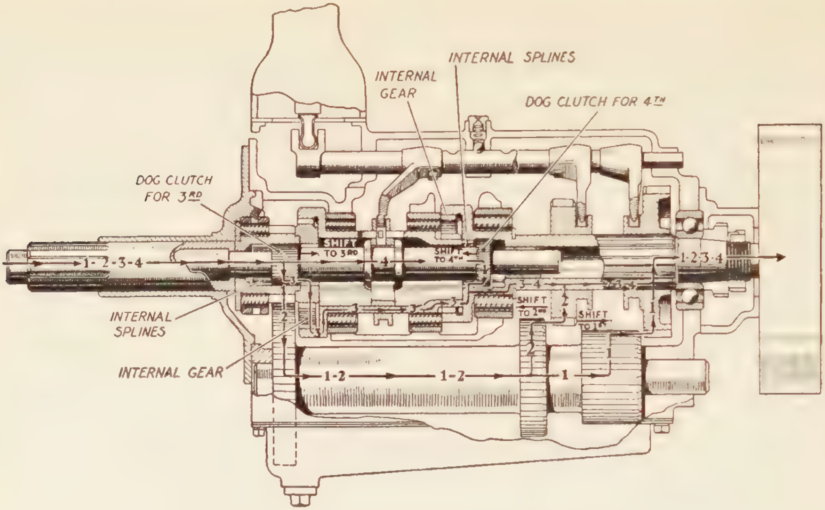

INTERNAL SPLINES
INTERNAL GEAR
DOG CLUTCH FOR 4TH
DOG CLUTCH FOR 3RD
1-2-3-4
SHIFT TO 3RD
SHIFT TO 4TH
4
3
3-4
SHIFT TO 2ND
SHIFT TO 1ST
2
1
1-2-3-4
INTERNAL SPLINES
INTERNAL GEAR
1-2
1-2
1

Figure 35.—Graham-Paige 4-speed transmission

of neutral. A latch on the gear-shift handle must be raised before first can be engaged.

82. Figure 36 shows the 4-speed transmission on the Chrysler 70 and 77. Fourth speed is direct, whereas third is secured through two pairs of internal-external gears. To understand the action on third, first note that the left pair of roller bearings supports a sleeve. The left end of this sleeve carries an internal gear in mesh with an external gear on the clutch shaft. The right

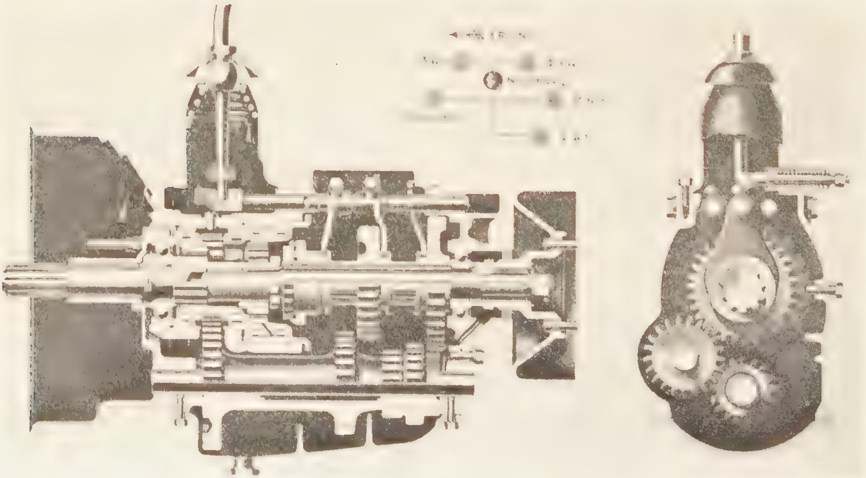


Figure 36.—Chrysler 4-speed transmission

end of the sleeve has an external gear in mesh with an internal gear which is carried in the two right roller bearings. The latter gear is connected to the main shaft by moving the dog clutch member to the rear, while sliding the dog clutch forward locks the main shaft to the clutch shaft, thus engaging fourth speed which is direct. Second, first and reverse are conventional in principle. The countershaft constant-mesh gear is driven by a gear which is integral with the sleeve previously mentioned.

SILENT SECOND GEAR

83. The Reo company has developed a new 3-speed transmission with silent second for its larger Flying Cloud, the Master (Figure 37). Second gear is so quiet that it is difficult to distinguish it from high. With the customary noise eliminated, second speed becomes a pleasant ratio for continued running where extreme nimbleness is required, as in traffic. It is also a welcome gear for running around another car on the open road. Shifting from second to high or conversely is unusually easy and the gear shift is standard.

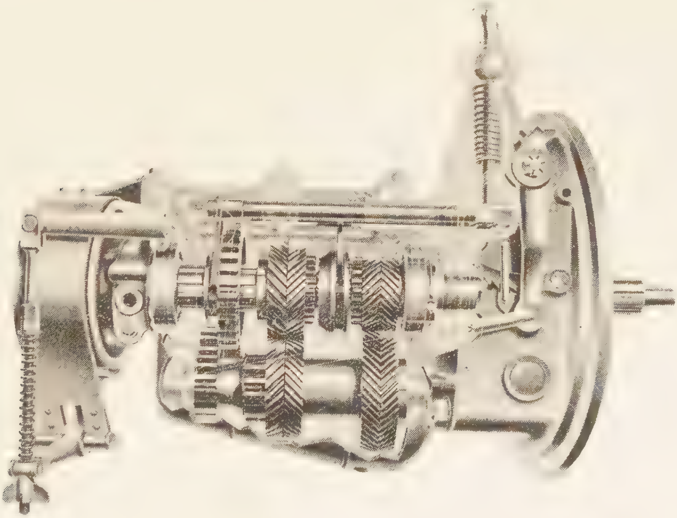


Figure 37.—Transmission with silent second in Reo *Flying Cloud* car

84. The new Reo transmission is particularly noteworthy because of its simplicity and ruggedness. It resembles a conventional 3-speed transmission with the main exception that the constant-mesh gears and the second gear train are the herringbone type. The Reo company, by extensive research, has discovered some new things concerning the herringbone principle and it is to them that the transmission owes its extreme silence and longevity.

85. The new transmission has the same bearings as the conventional type, it has the same number of gear units, the transmission case is only ¾ inch longer than the previous spur gear transmission and the transmission weighs only a trifle more.

86. As herringbone gears can not be slid in and out of mesh, a dog clutch is used for engaging second gear. The dog clutch is splined to the main shaft while second gear on the main shaft is freely mounted. When the dog clutch is slid to the rear, its internal teeth mesh with external teeth on main shaft second gear, thus locking the gear to the shaft. Moving the dog clutch forward from neutral engages high gear in the usual manner, internal teeth on the dog clutch meshing with external teeth on the end of the clutch shaft. Low gear and reverse are the same as in the conventional 3-speed transmission.

87. It seems almost superfluous to mention that conventional herringbone gearing is much quieter than ordinary spur gearing, but if this statement needs further explanation it should be sufficient to point out that a herringbone gear is really two helical gears. The comparative silence of a helical gear is well known but it produces objectionable end thrust, whereas in the herringbone gear, end thrust is eliminated because the thrust of the teeth on one-half of the gear is cancelled by the thrust on the other half.

88. While experimenting at the outset with herringbone, the Reo company found that if all the gears had the same pitch the transmission was not ideally silent, although it was much quieter than the spur-gear transmission. Further research eventually led to the discovery that if certain different pitches were used on the various herringbone gears, the silence on second became ideal. Thus the constant-mesh gears have one pitch, the two left sections of the second gear train have another pitch and the two right sections have still another pitch. Fundamentally, it is this feature which makes herringbone gearing suitable for a transmission.

89. It is not feasible at this time to offer the reader a complete explanation of why this particular combination of teeth is quiet, but at least it may be said that as there are three numbers of teeth or three pitches, the vibrations set up by any one pair of gears are opposed and effectively smothered by the different vibrations produced by the other gears, whereas if all the gears had the same pitch the vibrations would reinforce each other and somewhat noticeable noise would result.

90. Another herringbone gearing problem which has been successfully solved is that of alinement. Obviously, if both right and left sides of the gear train are each to do their full share of the work, alinement must be perfect at all times and if alinement is not ideal at all times undue noise and wear must result.

91. The constant-mesh gears aline themselves automatically because the countershaft gear cluster is free to slide slightly lengthwise on the stationary

countershaft. Similarly, the second gear train keeps in perfect alinement because main shaft second gear is free to slide lengthwise for a few thousandths of an inch.

92. The main shaft second gear, except when engaged, rotates continuously on the main shaft on hardened and ground steel to steel surfaces which are lubricated simply but positively by a radial hole running from the center of one of the many V's formed between each two pairs of teeth on the main shaft second gear. As the second gear train rotates, once during each revolution lubricant trapped at the base of this particular V is forced through the hole to the wearing surfaces.

93. With the new transmission a standard rear-axle ratio of 4.07 to 1 is used as compared to the previous standard of 4.42 to 1. The 4.07 to 1 ratio slows the engine down to the point where it is exceedingly smooth and quiet all the way up to 70 miles per hour and above. At the same time, the power of the engine is sufficient to provide lively acceleration and good hill-climbing ability on high.

94. On silent second the performance is unusual. Second gear provides a reduction of 1.67 to 1 which makes the overall reduction on second 6.68 to 1. This ratio is low enough to give exceptional acceleration and yet high enough to allow a maximum speed of approximately 50 miles an hour. Thus this gear becomes ideal for rushing around a car whether on the open road or in traffic while the gear is so inaudible that it is practically an "additional high."

BACK RUNAWAY PREVENTION DEVICES

95. Two automatic devices to prevent a car from rolling backward when stopped on a hill have recently appeared on the market. These are the "Kant-Back" and the "Noback."

96. The Kant-Back (Figure 38), is a device, mounted at the rear of the transmission, designed to prevent the car rolling backward when stopped on an up-grade. It is thrown out of action when the gear lever is placed in reverse, but comes back into action as soon as the gear lever is moved to neutral or to one of the forward speeds. To permit pushing the car around the garage or elsewhere, the gear lever is placed in reverse and then the clutch is held out of engagement by pulling a button on the dash which holds the pedal out, once

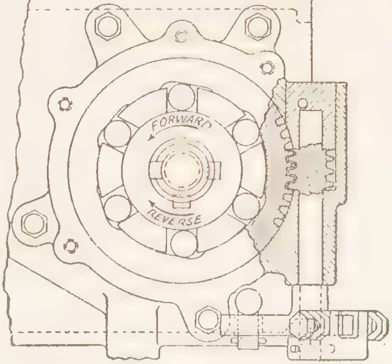
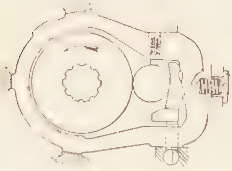


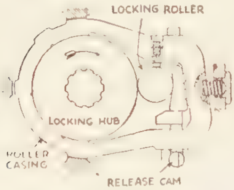
Figure 38.—Diagram of the "Kant-Back" device

it is depressed. The pedal may be released by pushing the button back in. The Kant-Back mechanism has no lost motion.

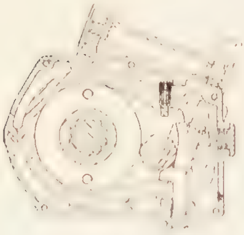
97. As shown, the device uses the over-running clutch principle. A series of rollers are placed between inner and outer races. The inner race is attached to the transmission main shaft while the outer race is held stationary by the worm and rack. A spacer integral with the inner race separates the rollers. So long as the shaft rotates forward the rollers rotate freely, but as soon as the shaft begins to rotate backward, the rollers are wedged against the "ramps" on the outer race. When the gear lever is placed in reverse the ramps on the outer race are moved back, far enough so that the rollers can not wedge against them. The outer race is moved back by the worm and rack mechanism which is operated by the reverse shifting mechanism.



FORWARD POSITION



LOCKING POSITION



REVERSE POSITION

Figure 39.—Three positions of the "Noback" device

98. The Noback (Figure 39), is not an adaptation of the over-running clutch principle; on the contrary, it is a brake with an automatic actuating mechanism. A small brake drum is attached to the rear of the transmission main shaft and just forward of the regular parking brake drum. Close to the drum is a half-round metal shoe held out of engagement by the coil spring at the right. Braking action is secured by bringing the self-centering shoe and drum into contact under sufficient pressure.

The actuating mechanism consists primarily of the roller and wedge shown. So long as the car is moving forward (top view) the roller is carried upward toward the thin part of the wedge and nothing happens, but as soon as the car starts backward, the roller moves downward onto the thicker portion of the wedge (middle view), pushing hard against the wedge which moves right, forcing the brake shoe casing right and thus bringing the half-round shoe into contact with the drum, pressure between shoe and drum being sufficient to hold the car on any grade the rear wheels will hold on.

When the gear lever is placed in reverse the device is thrown out of action by "knocking the prop from under the wedge" (bottom view). Suitable shafts and gearing actuated by the reverse shifter rod rotates a cam upholding the prop under the wedge, allowing the prop to drop, and the wedge to drop and move to the right as shown, with the result that the roller can not function. When the gear lever is moved out of reverse, the spring which returns the cam to its normal position is not strong enough to raise the cam against the weight of the prop, wedge and roller unless assisted by the forward motion of the car and therefore the mechanism can not go back into action until the car first moves forward—that is, disengaging reverse with the car rolling backward will not cause the device to function.

TRANSMISSION OF POWER TO REAR AXLE

99. The main shaft extends out of the rear of the transmission case and is connected with the drive shaft by means of a universal joint, which provides a flexible drive between the transmission and the rear axle. Power is transmitted from the drive shaft to the axle shafts by *bevel* gears (Figure 27). The axle shafts are at right angles to the drive shaft and bevel gears are required to give a right-angle drive. Inasmuch as the engine, on high gear, should make 4 or 5 revolutions to 1 revolution of the rear wheels, the bevel gear on the axle shafts is 4 or 5 times the diameter of the bevel gear on the drive shaft. The ends of the axle shafts are connected securely to the wheels. A typical differential mechanism mounted in a housing connected to the big bevel gear is shown in Figure 40, with details more clearly illustrated in Figure 41.

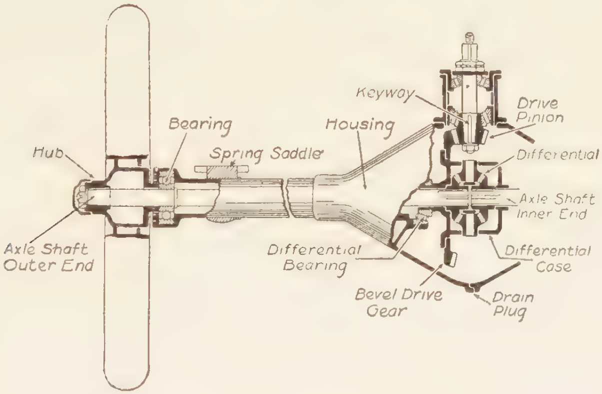

Keyway
Drive Pinion
Bearing
Housing
Hub
Spring Saddle
Differential
Axle Shaft Inner End
Axle Shaft Outer End
Differential Bearing
Differential Case
Bevel Drive Gear
Drain Plug

Figure 40.—Semi-floating rear axle

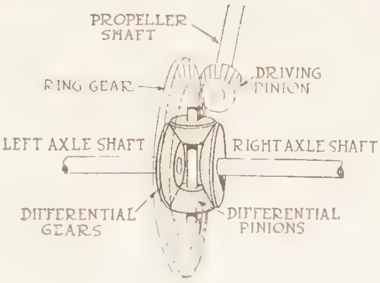

PROPELLER SHAFT
RING GEAR
DRIVING PINION
LEFT AXLE SHAFT
RIGHT AXLE SHAFT
DIFFERENTIAL GEARS
DIFFERENTIAL PINIONS

Figure 41.—Relation of gears in the rear axle

100. These illustration show that the ring gear does not drive the axle shafts direct, but merely rotates the differential housing mounted in it. Inside this housing are four gears—two differential

pinions mounted on a shaft in the housing mesh with a bevel gear keyed to each axle shaft. One differential pinion would work just as well as two. The two pinions do not alter the action of the mechanism; they merely distribute the wear and thus add to the strength and durability of the mechanism. As a matter of fact, it is not unusual to use four pinions, but only two are shown for simplicity.

DIFFERENTIAL

101. It will be remembered that the purpose of the differential is to compensate for the fact that the outside rear wheel runs faster than the inside rear wheels when rounding a corner; hence, a solid axle shaft running from wheel to wheel with the big bevel gear mounted at the center is impracticable. Some means of driving one wheel faster and the other wheel slower when rounding a corner is essential, and this is the function of the differential mechanism. When the car is moving straight ahead the differential is out of action; its gears are not revolving. In other words, when the car is going straight the two rear wheels are running at exactly the same speed. Now, the differential housing rotates continuously as a unit with the big bevel gear, and the differential pinions inside the differential housing are carried round and around but do not rotate on their shafts as long as the two rear wheels are traveling at the same speed; under these circumstances their function is to pull the bevel gears attached to the axle shafts around with them and thus rotate the wheels. Thus, these pinions are balance gears and split the power evenly, 50 per cent going to one rear wheel and 50 per cent to the other. But as soon as the car turns, the outside wheel demands *less* force for the simple reason that it still has only 50 per cent of the pushing to do, and it has a longer distance to do it in. In other words, the outside wheel has to run faster than the inside wheel, the result being that the small gears in the differential must rotate in such a way as to cause the outside wheel to rotate as much faster as required.

102. To state the matter another way, a certain force is required to drive the car whether it is moving straight or around a curve. Half of this force must be supplied by each rear wheel. Suppose that this total force is 200 pounds. This push is supplied by the engine and is split evenly between the two rear wheels by means of the differential mechanism. When the car rounds a curve each rear wheel must still supply the equivalent of a 100 pound push. Suppose the outside wheel moves 5 per cent faster and the inside wheel 5 per cent slower. Then the push required by the outside wheel would be 95 pounds and the inside wheel 105 pounds (approximately), while the distance traversed by the outside wheel is 105 per cent and the distance traversed by the inside wheel 95 per cent. In either case the product of force times distance is (95 x 105) approximately 100.

BRAKES

103. In this preliminary description of the car mechanism only rear wheel brakes will be considered. A brake *drum* is attached to each rear wheel and external *bands* grip the drums through the action of the brake pedal, thus stopping the car, while internal *shoes* are expanded against the drums by pulling the brake lever. The action of contracting and expanding brakes is shown in Figures 121 and 122. In the expanding brake it will be seen that movement of the brake lever causes the brake linkage to rotate the cam and spread the brake shoes so that they are forced into close contact with the drum. When the lever is released, springs pull the shoes out of contact with the drum. In the contracting brake it will be noted that the band is anchored against turning, about midway between the ends, and the ends are drawn together by a simple arrangement of levers connected with the pedal. When the foot is removed from the pedal, springs pull the band out of contact with the drum.

BRAKE LINING

104. Both the bands and the shoes are generally faced with brake lining, because metal-to-metal brakes are likely to overheat, cut and score, if unlubricated, and likely to slip if lubricated, intentionally or accidentally. Brake lining is made of woven asbestos tape the width of the band or shoe and about $\frac{1}{4}$ inch thick. This coarse woven fabric is impregnated with compounds baked in to increase the life and the gripping power of the lining, as well as to render it impervious to oil and moisture. The brake lining is riveted on.

TIRES

105. The function of the pneumatic tire is to cushion or absorb jarring caused by irregularities in the road, thus assisting the springs. The tires are able to smother numerous small bumps. The tire consists of two parts, the shoe and the tube (Figure 167). The shoe is strongly built of rubber and special cotton fabric and is designed to withstand the wear caused by the road, on the one hand, and the internal pressure of the tube, on the other. The shoe itself is not air-tight and does not need to be because the air is contained in the tube made of rubber about $\frac{1}{16}$ inch thick, which is air-tight. The tube has no strength to withstand the pressure within it, and does not need to have, because it is prevented from blowing up by the tire which surrounds it.

106. All road shocks are softened more or less by the tires, while the purpose of the springs is to soften still further the blows received by the

wheels, the result being that by the time the shocks received by the wheels reach the body their force is reduced to a comfortable margin.

107. The frame is the foundation which carries the body and the power plant, including the auxiliary units. It consists of two long steel side members, with some cross members (Figure 42). The frame rests on the springs and the springs are supported by the axles.

108. The wheelbase is the distance, usually measured in inches, between front and rear axles, the tread is the distance between the centers of the two front wheels or the two rear wheels. Standard tread on most cars is 56½ inches.

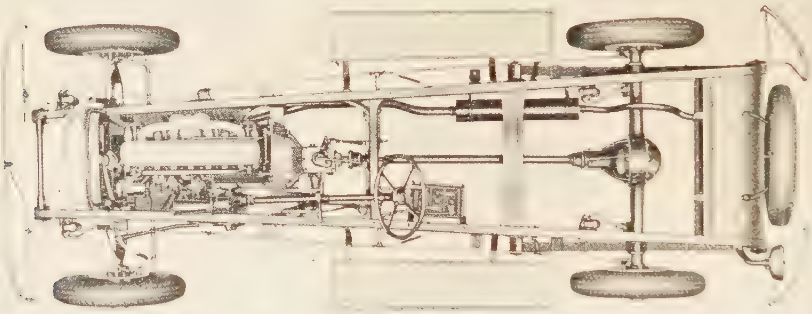


Figure 42.—Plan view of Marmon 78 chassis

STEERING GEAR

109. On horse-drawn vehicles steering is accomplished by pivoting the front axle at its center, so that when driving in a circle the axle as well as the wheels are swung to the right or left. The same is true of many toy wagons for children. On automobiles, however, it is usual to hold the axle stationary and to allow the wheels to pivot. The front wheels are pivoted on the ends of the front axle. Figure 43 shows how the spindle shaft on which the wheel is mounted is pivoted to the axle. Each spindle has a short arm ex-

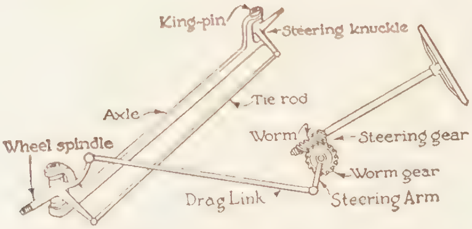


Figure 43.—Complete steering mechanism from steering wheel to axle spindles

tending to the rear and they are connected together by a cross rod called a *tie-rod* so that the two wheels swing to the left or right in perfect accord. The wheels are swung by moving the steering wheel. The steering gear may be defined as the mechanism which transmits the motion of the steering wheel to the front wheels. For satisfactory control of the car a relatively large movement of the steering wheel is necessary for a small movement of the road wheels, and some "irreversibility" is also desirable; that is to say, the steering gear should be so designed that shocks experienced by the road wheels will not be transmitted back to the steering wheel. Most steering gears are only partly irreversible, as complete irreversibility is considered to impose too heavy a strain on the steering mechanism. The worm-gear mechanism shown illustrates one of several methods for transmitting the motion of the steering wheel. A worm pinion is attached to the lower end of the steering-wheel shaft, which meshes with a worm gear to which is attached the *steering arm.* A drag-link connects this arm with an arm on one of the steering knuckles. Thus it will be plain that by turning the steering wheel the front wheels may be swung to right or left as desired.

Chapter II

ROUTINE OF CAR MAINTENANCE

201. Whether your car has a total life of 50,000 or 100,000 miles or more depends largely on how regularly you minister to it needs. Form correct habits in caring for a car, for it is no more trouble to treat it well than to treat it badly.

GASOLINE AND WATER

202. Examine frequently your fuel supply and the oil reservoir. Never take it for granted that there is plenty of fuel and oil. If you do, sooner or later you will run out of one or the other. Remember that neither gasoline nor oil gage register correctly when the car is sloping, either crosswise or lengthwise. For safety, the oil gage should never be allowed to register less than half full, for the reason that some lubricating systems do not work well when less than half full, and some systems are actually only one-quarter full when the gage shows one-half. Rather than run any risk it is best to keep the reservoir at least half full.

203. Form the habit of watching the radiator thermometer, ammeter, and oil-pressure gage unconsciously, and when any one of these three departs from normal see paragraph 1559 for thermometer troubles, paragraph 1337 for ammeter troubles, paragraph 726 for oil-pressure gage troubles.

204. Add distilled water or clean rain water to the battery once a week in summer and twice a month in winter. Many batteries are ruined by failure to add water regularly. Following this schedule it will frequently be found that no water is required; but do not be misled by this fact, for the following week you may find that the battery needs considerable water. The rate of evaporation depends on the air temperature and the amount of overcharging which the battery receives, as on a long drive.

205. Add water to the radiator once a week, or oftener if necessary. If the water in the radiator has boiled away, either wait until the engine cools before adding water, or fill radiator at a trickling rate.

206. Overhead valve rocker arms, if not provided with automatic lubrication from the engine, should be oiled or greased daily as required. Turn down any overhead valve grease cups daily and fill any oil holes daily.

207. See that all tires are properly inflated.

LUBRICATION

EVERY 250 MILES

208. The following points should be lubricated every 250 miles: All spring bolts; king-pin bearings (on which the wheels pivot); tie-rod bushings; drag link; steering gear (grease cup should be filled); clutch thrust collar lubricated (if provision is made); fan; water pump; generator; distributor shaft; starter; brake mechanism. A half-dozen drops of oil are sufficient for an oil hole, and a turn or two is sufficient for a grease cup or a grease gun. Spring bolts on half, three-quarter, and full-elliptic springs are usually found at both ends, quarter elliptic springs usually have no spring bolts, and cantilever springs usually have points requiring lubrication at each end and at the center. As a rule, medium cup grease is satisfactory for general use with a somewhat softer grease in cold weather. Sometimes a hard grease is required for the water-pump bearing in hot summer weather, and the same may be true of any other points exposed to high heat. Oil holes or grease cups on brake or clutch linkage, or rear axle should not be overlooked.

EVERY 500 MILES

209. No hard and fast rule can be given when to change oil. If the car is not equipped with an external oil filter, oil should be changed every 500 miles in cold weather and every 1,000 miles in warm weather. If it is equipped with an external oil filter, these figures may be doubled, except in cold weather, and if the car is also fitted with an effective crankcase ventilating system they may be tripled, except in cold weather, according to some authorities.

210. Be sure to buy a high-grade standard brand of oil in sealed cans. Never buy loose oil, and be sure that the cans you purchase have not been tampered with. When in doubt as to the character of oil to use, seek the advice of a reputable oil manufacturer; lacking this information, use a medium oil or a medium light oil.

EVERY 1,000 MILES

211. If the car is fitted with a magneto put two drops of light machine oil, such as Three in One, in each oil hole every 1,000 miles. In lubricating all electrical apparatus bear in mind that a tendency to under oil is better than a tendency to over oil.

EVERY 2,000 MILES

212. Add heavy oil to transmission and rear-axle housings. Many units will require slight replenishment after 2,000 miles, but it is best to be safe.

On other units, lubrication is a necessity every 2,000 miles to prevent their ruin. Inasmuch as one can not tell which type of units you have without the risk of ruining them, it is best to add lubricant once in 2,000 miles, as required.

EVERY 3,000 MILES

213. Fill the universal joints with a medium grease. Fill the steering-gear housing with a medium grease.

EVERY 5,000 MILES

214. Remove the wheel hub caps and fill them with a medium grease, and replace. Lubricate spring leaves. Tighten all nuts.

IMPORTANCE OF TIGHT NUTS

215. The importance of trying all nuts for tightness at least once every 5,000 miles can not be over-emphasized. Most breakages are due to loose nuts or neglect of lubrication. *Every* visible nut should be suspected of looseness. Even if few or no loose nuts are found, after the first 5,000-mile inspection, do not fail to make another thorough inspection at 10,000 miles, or oftener, if necessary.

216. The statement that *every* nut should be tested should be sufficient, but to emphasize the need be sure that the following nuts are tight:

All screws and nuts on wiring.
Cylinder head nuts.
Intake and exhaust manifold nuts.
Valve adjusting nuts.
Nuts holding rocker arm mechanism (if overhead valves are fitted).
Fan bracket nuts.
Motor support arm nuts.
Oil-pan nuts.
Nuts holding transmission to flywheel.
Generator and starter nuts.
Nuts on throttle and spark advance linkage.
Hose coupling screws or nuts, pump nuts and screws including gland nuts (if water pump leaks).
Nuts holding radiator to frame.
All nuts in dashboard and windshield.
If any screws in magneto (when one is fitted) are loose have them tightened by an experienced man.
All nuts in transmission housing.
All nuts in universal joints.

Nuts holding torque tube in place (if one is fitted).

All nuts on rear-axle housing, particularly the nuts holding the brackets which support the brake shafts.

All nuts on brake linkage. Also see that all cotter-pins are in place, properly spread and not worn out.

All nuts in and around the wheels, including the nuts holding the hub to the axle shaft, see paragraph 2102.

Spring clip nuts; important if spring breakage is to be avoided.

Spring bolt nuts.

All nuts on complete steering mechanism, including nut holding steering wheel on shaft, nuts on shaft coupling just above steering gear (if fitted), nuts holding steering-gear housing together, all lock-nuts on steering gear, nut holding steering arm to shaft, drag-link nuts, and all nuts on the front axle.

All nuts holding body to frame.

Hub caps.

Nuts holding fenders to frame.

Nuts holding lamps in place.

Nuts on one-man top.

217. Finally, tighten all other nuts not mentioned in this list but observed while working according to this schedule.

218. See that all castellated nuts are fitted with cotter-pins and that all other nuts subject to vibration are provided with lock-washers, or lock-nuts.

WARNING NOISES

219. Watch sharply for loose nuts and screws and tighten them as found. Most breakages may be avoided by tightening nuts in time. In addition to this all the nuts on the chassis should be gone over once every 5,000 miles, as already stated.

220. When an unusual noise develops do not operate the car any longer than necessary before it is repaired. Remember, also, that the more powerful a noise is the more likely it is to do serious damage.

CHAPTER III

RECONDITIONING YOUR CAR

301. This chapter meets a double need. It tells what to do to put your present car in prime condition, but more particularly it tells you how to remove the defects from a used car. A great many people are afraid to buy used cars because of the possibility of little but embarrassing troubles at unexpected moments, and a large number of those who do buy used cars have these troubles to their sorrow. Yet most automobile troubles are avoidable, and it is the purpose of this chapter to show how they may be avoided, as follows: Take your car to an electrical expert if possible, otherwise to your repairman. Tell him to install new high-tension wiring unless present wiring is in especially good condition, to adjust the breaker points, to test the coil and condenser, set up the spark-plug points, and examine and repair all low-tension wiring. If you have a Model T Ford, have the electrician true and adjust the vibrator points and clean, repair or replace the timer as required. Have him examine starter, generator and battery, and all starting and lighting wiring, making repairs as required. You are now practically immune from electrical troubles, including a stalled engine. If you wish to do this work yourself, see chapters on starting, lighting, and ignition.

302. Then take your car to your repairman. Have him flush out the radiator, change oil in engine, and have oil strainer cleaned, add oil to transmission and rear axle, grease universals and steering gear, wheel hubs, and all other parts. See paragraph 208 for complete directions regarding lubrication.

303. Have all nuts tightened, see paragraph 215.

304. Have gasoline tank drained to remove dirt. Drain carburetor. Have all strainer gauze in fuel system removed and cleaned. It is also a good plan to disconnect all gasoline pipes and blow them out with compressed air. It is possible that the reader may conclude that this advice regarding cleaning the gasoline system is a little overdone, but it must be emphasized that such is not the case. This work is necessary if trouble is to be avoided for 10,000 or 15,000 miles. Furthermore, as a rule, the fuel system may be given a complete overhauling as described in half an hour.

305. If camshaft is driven by chain, be sure to have chain adjusted if required.

306. Having done these things, the car is "stall-proof" for a year or two, except for breaker point adjustment every few thousand miles, or vibrator adjustment if you have a Ford Model T.

307. For the cure of specific defects, see Troubles.

308. In addition, it is advisable to make all other necessary adjustments and repairs, and therefore the following should be done, if required: Valves ground and carbon removed. Main and connecting-rod bearings adjusted. Steering gear adjusted. Clutch cleaned, adjusted or relined. Rear axle adjusted. Brakes relined or adjusted or both. Carburetor adjusted, etc. If you have a Ford Model T reline transmission bands if they chatter badly or fail to hold (see paragraph 1932).

TROUBLES TO EXPECT

309. Whether you are buying a used car or reconditioning your present car it is helpful to know what troubles to expect and when to expect them; this information is equally helpful in maintaining a new car.

CAMSHAFT GEAR

310. The gears driving the camshaft may become sufficiently noisy after 10,000 or 20,000 miles to require replacement. If the camshaft is chain-driven an adjustment may be required after the first 2,000 miles, with an adjustment about every 10.000 miles thereafter; a new chain may be necessary somewhere between 20,000 and 50,000 miles. A few cars have no provision for chain adjustment, therefore when the chain becomes too loose it must be replaced.

SPARK-PLUGS

311. Breaker points may require truing and adjusting every 5,000 miles, but they may run 50,000 miles without attention. The life of a good spark-plug is about 30,000 miles, although for best performance it is advisable to change them at 15,000 miles.

312. Spark-plug points should be cleaned and adjusted whenever the the carbon is removed.

313. All nuts should be tightened every 5,000 miles.

314. For best action, brakes will require adjustment from once a month to once a year, depending on the car and its use, while new lining will be required every year or so.

CARBON IN ENGINE

315. Carbon should be removed whenever the engine knocks sufficiently to give an objectionable reduction in power on wide open throttle, otherwise the knocking does negligible harm. Carbon removal may be postponed by

using high compression fuel. Periods of carbon removal will vary from 5,000 miles or more, depending on the engine, quality of oil used, and quality of the mixture. Too rich a mixture results in more rapid carbon accumulation. Valve grinding is required when the engine refuses to pull evenly at low speed with throttle open, if the cause of the trouble is not found elsewhere. Valve grinding will be required at 5,000 miles or more.

PISTONS AND BEARINGS

316. New piston rings may be needed at 10,000 miles or more, or whenever the oil consumption becomes exceptionably high.

317. New pistons and new rings may be needed at 20,000 miles or more, with or without cylinder refinishing.

318. New wristpins and bushings may be required at 20,000 miles or more.

319. New valves and new push rods may be needed at 20,000 miles or more.

320. Connecting-rod bearings may require adjustment at 20,000 miles or more.

321. Main bearings may need renewal at 30,000 miles or more.

ELECTRICAL PARTS

322. The generator commutator may require turning down and new brushes at 10,000 miles or more.

323. A battery will last from a year to several years depending on its quality and the care it receives.

324. High-tension wiring should be replaced every two years. Old wiring will cause loss of power and unreliable engine performance.

325. Chafed wiring, rotted insulation, loose connections, and dirty connections are likely to develop after a couple of years. The last, by the way, is responsible for the gradual dimming of the headlights.

CLUTCH AND TRANSMISSION

326. The clutch is likely to require cleaning and adjusting about once a year, but often relining will not be required during the life of the car.

327. Transmission gears, shafts, and bearings should last the life of the car, if given proper lubrication, and the same applies to universal joints, wheel bearings, and steering gear.

328. A new bevel pinion and ring gear may be required at 25,000 to 30,000 miles, although assuming reasonable quality and care these parts should serve 50,000 to 75,000 miles.

329. New king-pins and bushings, tie-rod pins and bushings, and drag-link parts may be required after 25,000 miles, depending on their quality and lubrication, although in many cases these parts are good for the life of the car. The same applies to spring bolts and bushings.

330. The frame may require re-riveting in some places, after 50,000 miles, although it may be more convenient to have the old loose rivets cut out and bolts put in.

OVERHAULING CAR

331. The foregoing schedule may also be used to advantage in overhauling your car whenever it may be necessary to do so. It must be added that complete overhauling of passenger cars is rather uncommon, the more popular method being to have each unit repaired as required.

332. If the car is to be laid up for several months, the storage battery should be turned over to a battery-man for safe keeping, otherwise it will slowly deteriorate to complete ruin. The car may be driven home by connecting four or five dry cells in series as described in paragraph 1144, or have a battery-man call and remove the battery.

333. Wash the car thoroughly before laying it up.

334. Drain the water from the radiator, and open any other drain cocks in the system.

335. Drain the oil from the engine, flush with a quart of kerosene, running the engine for a few seconds, then flush the engine out with some old cylinder oil running the engine for a few seconds, and finally fill the system with fresh cylinder oil, racing the engine at a fair speed for a minute so that all parts of the interior are covered with oil to prevent rust.

336. Block up all four wheels so that even if air leaks from the tires, no harm will be done. Little or nothing, however, is gained by deflating the tires.

337. Cover the car with sheets, or a paper cover bought for the purpose.

Chapter IV

HOW TO DRIVE

STARTING THE ENGINE

401. The engine may be started as follows (Figure 44). (1) Retard spark lever half way. (2) Open throttle about one sixth. (3) Pull choke out. (4) See that gear-shift lever is in neutral. (5) Turn on ignition switch. (6) Depress starter pedal or turn engine over by hand. The engine should start within half a dozen revolutions. Remove the foot from the starter pedal the instant the engine starts. Advance the spark lever all the way as soon as possible. If the engine is cold it may be necessary to assist it by rapidly closing and opening throttle about one quarter, until the engine runs without hesitation. Do not open the throttle too wide nor open it too abruptly when the engine is cold, because it is likely to stall. If the weather is warm, push the choke back in as soon as the engine starts but if the weather is cold, leaving the choke out will aid in running of the engine until it becomes warm. Most chokes are adjustable, in which case the choke

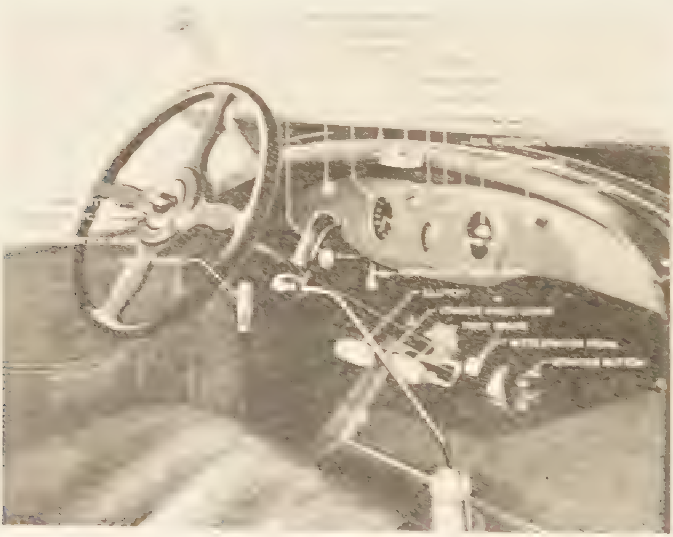


Figure 44.—Control mechanism of a Packard car

may be pulled out all the way for starting and pulled out perhaps half-way for running on cold days. If definite information is lacking, it is best to assume that the choke is designed merely to aid starting the engine and running until it warms up on cold days, and is not designed as a dash adjustment to the carburetor. The throttle may be closed as soon as the engine is warm enough.

402. The spark lever is invariably the shorter of the two levers (usually placed on the steering wheel), and in most cars it is advanced by moving it up. The hand throttle lever is the longer, and as a rule is moved up to open the throttle.

403. When in doubt as to how these levers work, watch the accelerator pedal while you operate the hand throttle lever. Depression of the pedal corresponds to opening of the throttle. If the accelerator pedal is all the way down with the hand lever all the way up, the throttle is open with the hand lever up. Similarly, the spark is advanced all the way with the spark lever up. For completeness, it should be explained that the accelerator pedal and hand throttle lever are two devices for controlling the throttle valve which is in the intake pipe. Either one may be used at the option of the driver. Model T Ford cars are not equipped with an accelerator pedal, although one may be installed for $2 or $3.

404. If the engine starts reluctantly, starting may frequently be aided by "flashing" the throttle rapidly between closed and half-way open positions. If the engine runs feebly when started, flashing the throttle may also aid in picking up speed.

405. If the engine is cranked by hand, pull up on the crank as quickly as possible, or "spin" the engine if possible. There is a knack in spinning an engine; the trick is to exert a rather constant pressure on the crank handle in its direction of rotation. If the starter crank is removable do not forget to put it back in the car after cranking the engine.

406. If the starting crank is missing and the starter refuses to work, the momentum of the car may be used to crank the engine, or the engine may be cranked by towing or by two or three men pushing. Another method which is occasionally successful is to put the car in high gear, jack up one rear wheel and crank the engine by turning the wheel in the same direction as it would rotate with the car running forward. This method is not generally feasible except with a small engine and a small rear-axle gear ratio.

407. Although it is permissible to crank modern cars with spark lever fully advanced, on some of the older cars the spark should not be advanced more than half-way or the engine is likely to run backwards for one or two revolutions (kick-back) and thus break or bend the starter mechanism or break one's arm if the car is being cranked by hand. As a rule, a back-kick is accompanied by two or three mild, sharp explosions in the carburetor, called backfires, but do not assume that all backfires are caused by back-kicks

408. Because of the danger of back-kicks when cranking an engine by hand it is wise not to allow the thumb to straddle the crank handle, but keep it on the same side of the handle as the fingers. Further, it is safer to use the left hand than the right (on all cars which crank clockwise). Also it is safest to pull up on the handle and never to press down on it. By following these suggestions, if a back-kick does occur, the crank handle will simply unbend the fingers and no harm will be done. But if a back-kick occurs when the thumb straddles the crank handle, the hand is caught and some bones must break. Likewise, if a back-kick occurs when pressing down on the handle it may cause breakage of bones.

409. There is some danger in spinning an engine because it is necessary to press down as well as pull up. Therefore, when half turns up prove unsuccessful in starting the engine and spinning must be tried, stand as far away from the crank as possible; this is feasible on small and medium size engines, but it is impossible on larger ones. If in doubt about spinning a strange engine, spin it with the ignition off, having an assistant turn the ignition on as soon as spinning is up to speed. A back-kick is unlikely with the engine spinning at top speed.

410. If the engine is not equipped with a choke, on cold days it may be necessary to flood the carburetor by holding the *float* needle valve off of its seat until fuel leaks out of the carburetor. Also see paragraph 1522.

CONTROL MECHANISM

411. The control mechanism must be explained before correct driving methods are described. The clutch pedal is invariably the left one and the service brake pedal is the right one. The small pedal within convenient reach is the accelerator pedal; the starter pedal is usually somewhat further away to the right or under the driver's heel, although a few engines are started by closing a switch on the dash. The few cars fitted with muffler cutouts ordinarily have some sort of a pedal device for opening the cutout. The hand brake is always provided with a ratchet so that it may be locked in place. Occasionally, the service brake and clutch are both actuated by the left pedal, in which case the right pedal is likely to become the emergency brake, and is supplied with a ratchet. The hand brake is rarely more powerful than the foot brake and is usually less powerful. It is an emergency brake only in the sense that it is a reserve brake in case the foot brake fails.

412. Most cars employ the so-called standard gear-shift lever arrangement (Figure 29). Reverse is to the left and forward, low to the left and rearward, second to the right and forward, and high to the right and rearward. On all cars equipped with 3-speed sliding-gear transmissions the handle of the gear shift lever describes an H in going through the various gears from

reverse to high. In cars not using the standard shift the H shown in Figure 29 may be turned around or upside down. Nevertheless, in all 3-speed transmissions, reverse and low are always directly opposite and so are second and high. Also low and second are always diagonally opposite. Check these statements with Figure 29.

413. When in doubt as to the gear-lever positions for reverse, low, second, and high, the latter part of the foregoing paragraph indicates that it is only necessary to find one gear to determine the others. As a last resort, with the engine running slowly, place the gear lever in one position after another, letting the clutch in gently each time, until reverse is found. As soon as reverse is found the other gear positions are known; low is opposite reverse; second is diagonally opposite low; high is opposite second.

414. On cars equipped with four speeds forward and one reverse, reverse is usually opposite second; third is diagonally opposite second; and fourth is opposite third. First gear may be at one side. Direct drive is generally on fourth, although third is sometimes direct with fourth over-geared for high speed.

415. A few older cars and trucks use a gear shift in which the various gears are engaged progressively. Moving the lever all the way forward gives high, whereas reverse is all the way to the rear (or conversely) with second and low in between. Neutral is generally placed between low and second.

416. Some trucks are equipped with more than four speeds forward, usually by placing a 2-speed sliding-gear transmission in series with a 3- or 4-speed transmission, the two being in the same housing or in separate housings. Thus, with a 2- and 3-speed combination, with high gear engaged on the 2-speed transmission, any one of the three speeds on the other transmission may be used; likewise with low gear engaged on the 2-speed transmission, all three speeds on the other transmission may be used. Either gear-shift lever may be manipulated as required, because the two are independent.

417. With automatic gear-shifting systems the ordinary method is to move the selecting lever to the gear desired, the gears being subsequently shifted whenever the clutch pedal is pushed out all the way.

418. The Ford Model T control mechanism differs considerably from that used on all other cars (Figure 45). There is a hand brake and three pedals. The left pedal engages low gear when held down with the foot and high gear when released. There is no intermediate or second gear. As long as low gear is wanted the foot must remain on the pedal. This pedal has a neutral position in which neither high nor low is engaged, obtained by pressing the pedal slightly. At this time reverse may be obtained by pressing the middle pedal. The right pedal is the service brake. The hand brake is similar in appearance to that on other cars, but when it is fully applied the car is in neutral, neither high gear nor low gear being engaged. If desired, it may be applied enough to bring the pedal to neutral, but not enough to cause

the rear brakes to act. This hand brake should only be used to secure the car when standing still, or if the foot brake fails. If the hand brake is used when running, the brake shoes will wear out in a short time.

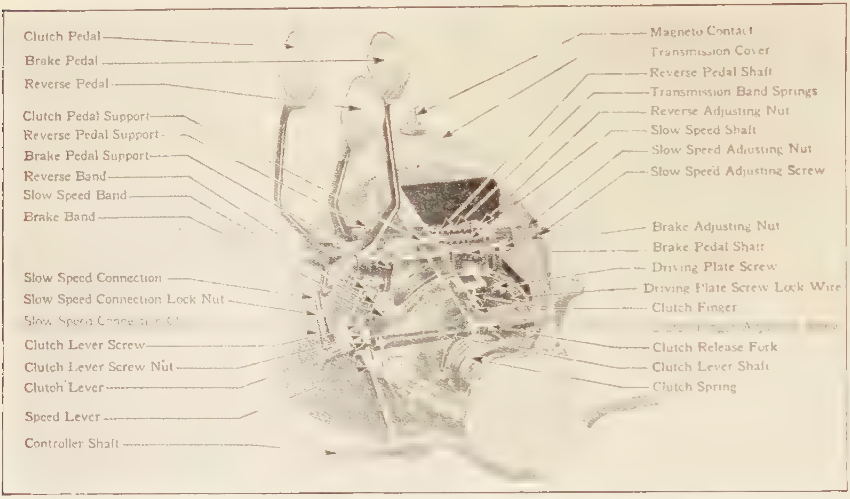

Clutch Pedal
Brake Pedal
Reverse Pedal
Clutch Pedal Support
Reverse Pedal Support
Brake Pedal Support
Reverse Band
Slow Speed Band
Brake Band
Slow Speed Connection
Slow Speed Connection Lock Nut
Slow Speed Connection [illegible]
Clutch Lever Screw
Clutch Lever Screw Nut
Clutch Lever
Speed Lever
Controller Shaft
Magneto Contact
Transmission Cover
Reverse Pedal Shaft
Transmission Band Springs
Reverse Adjusting Nut
Slow Speed Shaft
Slow Speed Adjusting Nut
Slow Speed Adjusting Screw
Brake Adjusting Nut
Brake Pedal Shaft
Driving Plate Screw
Driving Plate Screw Lock Wire
Clutch Finger
Clutch Finger Adj [illegible]
Clutch Release Fork
Clutch Lever Shaft
Clutch Spring

Figure 45.—Control mechanism of a Ford Model T car

419. Under normal running conditions the car should be operated with the spark lever advanced from three-quarters to all the way. Most cars may be operated with the spark advanced all the way on all gears, and under all circumstances except when the engine is running slowly with throttle wide open, as in ascending a hill on high gear. If the engine knocks at this time the spark should be retarded just enough to stop the knock. The hand throttle is usually maintained in its closed position, the engine being controlled entirely by the accelerator pedal. If the engine stalls with the throttle closed and the clutch out, open the throttle sufficiently so that stalling is avoided, and regulate the low speed adjustment on the carburetor and the throttle stop on the carburetor, as described in paragraph 923. The hand throttle may be used to the exclusion of the accelerator pedal if the driver prefers, although the accelerator pedal is generally considered more convenient, and safer, because the driver then has both hands free for the steering wheel.

CORRECT DRIVING

420. Almost any motor-car owner willing to try can become an expert driver. Yet there are comparatively few excellent drivers because there are few excellent teachers. The instruction of most drivers has been neglected.

When a man buys a motor car for the first time the seller usually gives him just as little instruction as he can. Often the new owner learns so little that he is a menace to the public for months. Then this man who has learned imperfectly teaches the members of his family, or others.

421. Correct driving may well be defined as manipulating the car with fullest consideration for the car and its passengers. The comfort of the passengers comes first. Therefore quick starts and stops should be avoided and turns should be taken smoothly and not jerkily, at moderate speed, while speed should be reduced for rough roads and bumps. The habit of engaging the clutch gently, shifting gears silently, applying the brakes moderately will have a salutary effect on the life of the car and its freedom from repair expense. Learning to drive safely must also be considered a prime accomplishment.

CLUTCH AND GEARS

422. Clutch and gears should be manipulated smoothly and silently. Most rear-end trouble is caused by engaging the clutch too abruptly, while noisy gear changing chips little pieces off of the clashing teeth. The gears on any car may be shifted quietly unless clutch or transmission require repairing or adjusting. It is merely a matter of learning how. A shift is silent when the teeth of the two gears being meshed are moving at about the same speed, whereas if the speeds are widely different a clashing noise will be heard. Therefore, in shifting from low to second or from second to high the engine speed must be reduced while the shift is being made, while shifting from high to second or second to low the speed must be increased to that demanded by the new gear. In shifting up, the exact method to pursue depends on the car, and experiment alone can determine the exact procedure. Some clutches must be pushed out all the way, others just a trifle less, and others half-way. Sometimes, best results are obtained by full depression in shifting from low to second and less than that for second to high, or conversely. When the engine is cold, less than full depression may be best with full depression when the engine has warmed. In other words, if any difficulty is experienced in securing a silent shift, vary your clutch pedal movement until you have found the cure. If a silent shift is still impossible, see paragraph 1913. To make a silent shift upward it is generally necessary to wait for an instant in neutral. This interval will be almost instantaneous on some cars and may be a second or so on others. And the interval necessary on any particular car will increase as the speed of the car is increased—that is, if the interval is 1/10 second when traveling 2 miles an hour on low gear it might be ½ second when running 10 miles on low.

HOW TO START

423. With these things in mind and assuming that the engine is running at minimum speed the car should be started as follows: Push the clutch pedal (left pedal) out all the way and after waiting an instant bring the lever to low-gear position (Figure 44). If any difficulty is experienced in engaging low, move the lever back to neutral, engage the clutch for a moment, then push it all the way out and try again—and again if necessary. With the clutch out *all the way* if the gears clash and low gear can not be easily engaged, move the lever quickly with some force. This condition indicates that the clutch is probably dragging; for remedy see paragraph 1913.

HOW TO SHIFT GEARS

424. Place the right foot on the accelerator pedal and speed the engine a trifle; there is no need to race the engine. Then let the clutch in just as slowly and gently as possible, and the car will get into motion without the slightest jerk. As soon as the car is rolling, shift to second; there is no need to accelerate to 6, 8, or 10 miles an hour on low unless the start is made on a rather steep hill. Shifting to second is accomplished by simultaneously depressing the clutch pedal, raising the foot off of the accelerator pedal, and moving the gear-shift lever to second as soon as the clutch is disengaged (always be careful not to shift to reverse by mistake). Then re-engage the clutch and depress the accelerator so that the engine will take up the load. The series of movements just described should be made without loss of time, but not so abruptly that there will be any jerk to the motion of the car. Take time in learning to drive. In all your movements be deliberate; speed will come with practice. Be prepared—have your hand on the gear-shift lever before you push out the clutch pedal.

425. Shifting from second to high is similarly accomplished, but the car should be running 8 to 15 miles an hour except when ascending a hill, in which case a higher speed may be required before shifting, assuming that the car is capable of ascending on high. When shifting up on a hill it is usually desirable to make the shift without waiting in neutral for even a fraction of an instant, as loss of momentum must be prevented.

426. In making a silent shift it is better to err by shifting too quickly with too small an interval in neutral. If you wait too long in neutral you may miss the gear entirely, with the result that no amount of clashing will effect an engagement. When this happens, many drivers bring the car to a stop and start all over again. But this is not necessary. If you are shifting, for example, from second to high and you miss high by waiting too long, immediately engage the clutch with the gear lever in neutral and then speed

up the engine to the rate which would be required to drive the car in high at the rate it is coasting at the moment; then disengage the clutch and shift to high.

COASTING

427. The same method may be used when coasting. Suppose that you have been running down a long hill with the gear lever in neutral and the engine shut off: At the foot of the hill you wish to start the engine. (Unless the car is moving slowly, high gear can not be engaged and therefore starting the engine by the momentum of the car is out of the question.) Retard the spark half-way, turn on the ignition switch, step on the starter pedal, and when the engine is running, speed it up to a *slightly higher rate* than that demanded by high gear, push the clutch out and shift to high. If the engine has not been shut off, simply speed it up and shift to high.

428. In coasting, if you wish to start the engine by the momentum of the car, it is necessary to keep the lever in gear and coast by holding the clutch out. At the bottom of the hill let the clutch in gently with the throttle closed until the engine takes hold.

429. The engine may be cranked by gravity when the car is parked on a hill. With the clutch out, high or second gear must be engaged before the car moves more than a few feet and the clutch is held out until the car has gained enough speed to crank the engine. Let the clutch in gently with the throttle closed. High is the best gear for starting the engine, although second is sometimes preferred if the grade is slight and there is some question as to whether sufficient speed can be obtained to crank the engine on high. It takes a skillful driver to crank an engine in low or reverse, especially the latter. If these gears are used, engage the clutch gently.

430. If you live in hilly country you will find that it will save the battery to contrive to start on a hill whenever possible, especially in winter, when short runs, short days, and frequent stops tend to draw more current from the battery than is put into it. If you wish to start by gravity be sure that you park the car pointing down hill.

SHIFTING TO A LOWER GEAR

431. With a little practice almost every driver learns to shift upward silently, but few ever learn to shift down silently. The usual method when a shift to second or low is made on a hill is to close the throttle, depress the clutch, and shift as quickly as possible. The car loses momentum while the throttle is closed and the clutch disengaged, and if there is any appreciable delay the car may come to a stop. This method is always accompanied by more or less gear clashing.

432. Fortunately, the correct method is as simple as it is satisfactory,

and is guaranteed to work under all conditions and on all cars. Suppose, for example, that you have been climbing a hill on high, gradually losing speed until a point is reached where a shift to second is advisable. The throttle, of course, is wide open because you have been trying to make it on high. You will remember that in order to make a quick, silent shift to second the engine speed must be increased rapidly, and loss of car momentum during the shift must be minimized by disengaging the clutch as short a time as possible.

433. These conditions are met by the following method: With the throttle wide open, depress the clutch pedal so that the clutch slips just enough to permit the engine speed to rise the required amount for driving the car on second gear. As soon as this speed is reached, shift to second, and let the clutch back in. In practicing this shift, proceed slowly and deliberately, but after a little skill is obtained speed will be acquired. This shift can be made in a fraction of a second—so quickly that in shifting from high to second on a 20 per cent grade or from second to low on a 30 per cent grade no noticeable loss in car velocity is noted. Shift to second whenever the engine is unable to pull the car on high, and to low when the engine is unable to pull the car on second. Always shift before the engine begins to buck or labor. After skill is acquired, any tendency of the engine to race may be avoided by closing the throttle slightly as soon as the engine has reached the desired speed.

434. When shifting down on the level or down hill, it is not necessary to hold the accelerator open more than half-way. A shift from high to low may also be made in the manner described. It should be remembered, however, that the engine must be run about three times as fast on low as on high. Never shift from high to low at a greater speed than 10 miles an hour unless an emergency arises. Shifts to low at 20 to 25 miles per hour are feasible if (ever) necessary, by racing the engine full speed, before making the shift.

435. It should also be pointed out that a shift from low to high may be made when desired, the method being no different from that described for a shift from low to second or second to high, except that a longer wait than usual is required in neutral. If desired, in starting the car second gear may be skipped, the driver going directly from low to high. A finished driver, however, is likely to go from low to high only in starting down a hill, and even then he may start in second or high, probably using the car to crank the engine.

436. Any car may be started on high or second, but the former is not advisable because of excessive clutch wear. The clutch must be slipped slightly when starting on low, more when starting on second, and most when starting on high. Slippage wears the clutch and should be avoided as much as possible. A quicker start can be made by going through all three gears. If the clutch "grabs," a smoother start may be made in second or high.

437. Never shift from a forward gear into reverse or conversely except when the car is standing still. This admonition, however, does not apply to a Ford Model T if the shifting is not done too strenuously.

USE OF BRAKES

438. One of the distinguishing marks of the finished driver is the way that he uses his brakes. For the comfort of the passengers and the good of the car, brakes should be used as little as possible. Many times, when it is necessary to slow down, reduced speed may be obtained by coasting, rather than by running full rate until the last instant and then applying the brakes hard.

439. To make the quickest stop the brakes should be applied as hard as possible without causing the wheels to slip. Slipping is not only bad for tires, but a sliding wheel has much less retarding effect than a rolling wheel. This rule applies not only to dry roads, but wet asphalt, but of course, in the latter case the wheels slip so readily that the brakes can not be applied with full power, which means that when driving on slippery roads a slower average speed should be maintained. When a car starts skidding on icy streets or wet pavement the clutch should be disengaged, the brakes released if they are on, and the front wheels should be turned so as to bring the car out of the skid. When applying the brakes it is not necessary to disengage the clutch until the car speed gets down to 4 or 5 miles an hour. Leaving the clutch in when braking above this speed not only saves the driver the effort of clutch disengagement, but it aids in braking the car.

ENGINE BRAKING

440. Instructions concerning braking, paragraphs 441 to 451, apply especially to cars with two-wheel brakes. With four-wheel brakes *properly equalized* the advice given may be roughly discounted 50 per cent. Also it should be noted that on long mountain grades averaging about 10 per cent, for example, wind resistance balances the effect of the grade at a speed of 35 or 40 miles an hour, so that if it is safe to descend the grade at this speed in high gear, no brakes are required except perhaps for an occasional turn.

441. If both sets of brakes are in *good* condition the additional safety factor obtained by using the engine as a brake is slight. However, inasmuch as you can never tell when brakes are going to fail, the safest plan is to shift to low on steep hills. With the throttle closed, no difference in braking effect is ordinarily noted with ignition on or off, and it is advisable to leave the ignition on to prevent possible fouling of the spark plugs. On the Ford Model T, the reverse pedal may also be used as a brake, provided that it is not applied with force enough to stall the engine.

442. If you are descending a steep hill more than 1/4 mile long it is advisable to use second or low, depending on the steepness of the hill, to prevent burning of the brake lining. If the hill is exceptionally steep and several miles long, as might be the case in descending a mountain, there is some danger of burning the brake bands, even in low, unless the car is operated slowly. Even then it may be advisable to throw water occasionally on the brake drums to cool them.

443. There are other ways of avoiding burned brake lining in descending a long steep hill. If you use the foot brake and hand brake alternately, changing from one to the other every 1/8 mile or so there is little likelihood of burning the lining, especially if hand and foot brakes act on separate drums.

444. Expanding brakes with air-cooling fins on the drums may be used almost indefinitely in descending steep hills without danger of burning the lining, even though the engine is not in gear, provided of course that the air-cooling fins are adequate in design.

445. Cars equipped with brakes on all four wheels have twice the braking surface as cars with rear wheel brakes only, and therefore there is less danger of overheated lining. If it be assumed that the front wheels have about the same braking power as the rear, the use of the engine in gear should be necessary only in descending exceptionally long, steep hills.

446. Most modern cars can climb a 10 per cent grade on high gear, yet a 10 per cent grade more than 1/2 mile long is likely to damage the brake lining if the rear brakes are used without assistance. If the brakes are badly equalized, so that the brake on one rear wheel produces say 10 per cent of the retarding effect while the other brake produces 90 per cent, the brake lining may smoke even in descending a short steep hill. In using the engine as a brake, employ the same gear going down hill that you would require going up, although this rule must be modified slightly, inasmuch as it holds only for cars that are average hill-climbers. If your car is an exceptionally good hill-climber, assume that it is average when applying this rule.

447. There is no reason why it should be necessary to make a quick, downward shift when you wish to brake in second or low gear. The presence of a steep hill may usually be sensed in advance by the general appearance of the country, even though the hill itself can not be seen. But even if there is no forewarning of a steep hill, a motor-car operator who "outdrives his eyes" is foolish. The downward shift should be made in the manner already described, the throttle being closed the instant that the shift is accomplished and before the clutch is let back in.

448. There are some important additional reasons for using the engine as a brake as occasion arises. If the brakes are weak or ineffective or if one set of brakes is practically useless, second gear should be used on all moderate hills and low gear on all steep hills.

449. If the brakes do not equalize satisfactorily, low gear is advisable on all steep hills known to be slippery or where circumstances indicate that the surface may be slippery. This advice may be ignored on all cars equipped with an adequate transmission brake.

450. Aside from saving the brake lining, second or low gear is often advisable to reduce the braking effort that the driver must exert. On hills that are hardly long enough or steep enough to require the engine as a brake, the car may be brought down safely with minimum effort by applying the hand brake part way and supplying the remainder of the braking effort with the foot. If the slope of the hill does not vary, the hand brake alone may be used. It is necessary to supplement the hand brake by the foot brake when the slope of the hill varies considerably.

451. Many drivers consider that a quicker stop may be made in an emergency by shifting to second or low and using the engine as a brake in addition to applying the brakes as usual. This idea usually is correct only when the brakes are incapable of locking the wheels. Obviously, if the brakes have power enough to lock the wheels any additional braking effort which the engine supplies must be superfluous. But if the brakes can not lock the wheels, the braking effort of the engine may be of value in proportion to the weakness of the brakes. Maximum braking power, of course, is secured by applying the brakes almost but not quite enough to lock the wheels, and braking power is greatly reduced by locking the wheels.

BAD ROADS

452. Slippery roads should be taken at reduced speed, whether the insecure footing is due to oil, water, mud, snow, ice, sand, gravel, or loose stones; all of which are greatly to be feared on steep hills. Chains are desir-

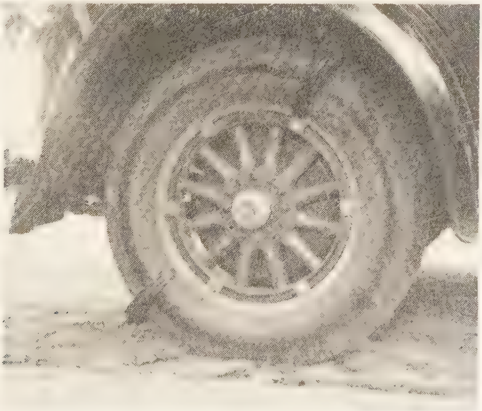


Figure 46.—A mudhook for securing traction in deep mud or snow

able in driving through deep mud or snow. In deep mud, chains on all four wheels may be required, those on the front wheels giving steerage. When touring in the country, when chains are required but not at hand, it is worth while remembering that almost every farmer has a supply of 1-inch rope which he will be willing to sell, except during haying and harvesting. This rope should be wound around the tire and between the spokes. If the mud is hub deep it is possible that neither chains nor heavy ropes will prove adequate, in which case mud hooks (Figure 46), are recommended. At least two should be attached to each rear tire.

HOW TO APPLY CHAINS

453. Arrange the chains as shown in Figure 47, by rolling the car back on them—or jack up the wheels and lay the chains on with the ends hanging down. Connect the inner ends and then the outer ends, being careful that the chain is neither tight enough to bind on the tire nor loose enough to fall off. When traveling in mud or snow it is important to apply the chains so that the slipping of the wheels when going forward tends to close the locking links. In addition it may be advisable to wrap several turns of iron wire around these links.

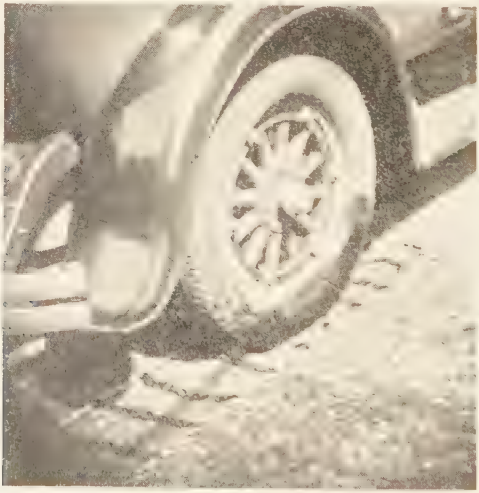


Figure 47.—Applying a chain without jacking up a car

454. When a car is slightly mired or stuck in snow, it may sometimes be extricated by see-sawing it back and forth in reverse and low. If help is available a better method is to have somebody push the car. Generally, when a car is stuck in anything less than a snow drift, one man pushing

while the driver is spinning the wheels will extricate the car in a moment. Avoid deep mud holes in so far as possible. Not only is the car likely to become mired, but there is danger of breaking a spring. Roads rutted with mud or snow should be taken as slowly as possible as the strain on the car in dropping into holes and skidding from one rut to another is severe. In parking the car or in turning around on a road, or in making any other manuvers, be careful not to mire the car in soft mud at the side of the road, or in deep snow. If in doubt, examine the footing. Also watch for soft ground and sand when it is necessary to drive across a field.

455. When a single deep mud hole or a stretch of muddy road is encountered, especially when there are no chains, ropes or mud hooks available, the best advice is to keep going, if possible. If the car stops, the rear wheels will quickly dig themselves in until the rear axle rests on the ground; therefore, keep going at as lively a pace as seems feasible, using second or low as required. Once the car stops, instead of spinning the wheels it is best to halt and consider the situation. Apply chains, rope, or mud hooks if possible or necessary. Often the best method is to back out slowly, slipping the wheels as little as possible, but try not to allow the car to stop until it is on firmer ground. Once out, it is possible that a detour may be taken, or a more favorable path through the mud may be found, or if it is necessary to follow the same tracks rush the mud hole at 15 to 25 miles per hour, let us say.

456. If the rear wheels slip because of a slight snow fall, traction may often be secured by allowing the wheels to spin until they wear down to the ground. Once the car is in motion further stalling may often be avoided. In deep snow, if the car is equipped with chains it may be necessary to allow the chains to wear down to solid ground to start the car. Some times it may be necessary to back off and rush the drifts, breaking through them gradually; then again it may be necessary to shovel the snow out of the way. These extreme measures are only likely to be employed for a short distance, as in driving from a private garage to the street. If the chains come off when used in deep snow, wire the fasteners on the chain ends securely in place, being careful that the chain is so placed on the wheel that the rotation of the wheel in the forward direction will not tend to open the fastener. The same precaution may be required in deep mud.

PARKING A CAR

457. When parking the car on a hill the front wheel adjacent to the curb should be cramped sharply against it. Drive the car within 4 or 5 inches of the curb. Assuming that the curb is to the right of the car, the steering wheel should be turned *sharply* to the left when the machine is pointed up hill and to the right when pointed down hill (Figure 48). Be sure the

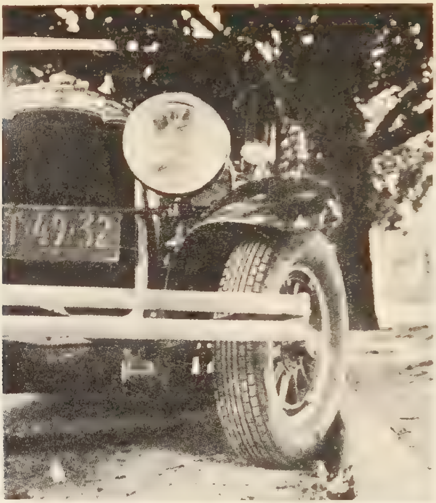


Figure 48.—The wheel should be cramped sharply to the curb when a car is parked on a hill

wheel is in *firm* contact with the curb. The emergency brake should be applied hard and as an additional precaution the gear lever should be placed in low or reverse, and the ignition switch or gear lever should be locked to prevent children starting the car. In addition, on a steep hill it is advisable to block one of the wheels with a stone (Figure 49). If you own a Model T Ford, blocking the wheels is most essential, as there is only the hand brake to keep it from running away, and that alone is too small a margin of safety.

458. When parking the car along a curb where the space available is little longer than the car, the best way to squeeze into it is to drive up along-

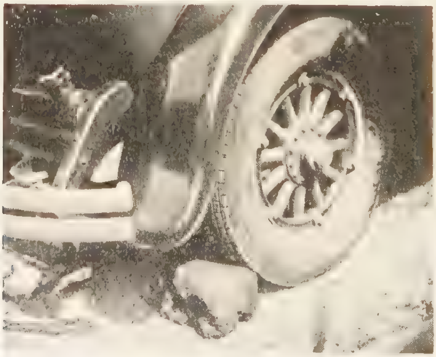


Figure 49.—A stone such as shown behind the rear wheel helps to hold a car on a steep slope

side of the car directly in front and then back in. Always be careful to allow a space of 4 to 6 inches between wheel and curb to facilitate driving away. When the car is stopped or parked, the emergency brake should be applied for the reason that unless you form the habit, some day you will unwittingly park the car on a slight grade, and after you have left, a passing truck or street-car may jar the car loose and serious damage may result.

459. In starting the car at any time be sure to release the emergency brake all the way and form the habit of trying the brake again as soon as you are under way in high gear.

STARTING UP HILL

460. When starting the car upward on a hill, no special method is required if a wheel is blocked or if the front wheel is cramped against the curb, because the car will not move when the hand brake is released. It is necessary, however, to open the throttle wider than usual while the clutch is being engaged to prevent stalling of the engine.

461. If the car is held solely by the brake, the easiest way for the beginner to get the car in motion is to apply the hand brake, and then push out the clutch and bring the lever to low-gear position. Then the accelerator pedal is depressed, the clutch engaged and the brake released simultaneously. While these three operations should be done simultaneously, there is no reason why the driver should not proceed slowly and deliberately. There is no need for hurry.

462. By using the hand throttle instead of the accelerator pedal the right foot may be applied to the foot brake. In this case the clutch is engaged and the brake released as the hand throttle is opened.

463. After skill and confidence have been obtained the following method will be found preferable except on exceedingly steep hills: Holding the car with the foot brake, the clutch is pushed out and low gear engaged, then the right foot is quickly removed from the brake and applied to the accelerator pedal, this pedal being depressed as the clutch is engaged The car may roll back a few inches while the clutch is taking hold, but no harm will result provided that the clutch is engaged gently; but something is likely to break if the car rolls back several feet and then the clutch is abruptly engaged while the engine is racing. This method will not work satisfactorily if the clutch grabs.

464. When it is necessary to drive at a lower rate than the minimum speed on low gear, the clutch may be slipped as required. Never allow the foot to rest on the clutch pedal except when the clutch pedal is being used. Failure to observe this rule may result in the clutch thrust bearing or collar wearing out in a short time.

465. When the car is parked, form the habit of bringing the gear lever to neutral and putting on the hand brake, or put the lever in low or reverse if you wish this additional braking effect. Do not forget to turn the ignition switch off, and do not overlook turning off the lights when the car is left in the garage at night.

466. For easy starting, stop the engine as follows: Speed the engine up somewhat, and open the throttle wide the instant the ignition is turned off, holding the throttle open until the engine stops rotating. In addition, in cold weather, it is a good plan to pull the choke out, before proceeding as outlined above.

467. Form the habit of watching unconsciously your oil-pressure gage, ammeter, and radiator thermometer and when they fail to register properly look up their symptoms under Troubles. Do not fail to heed any unusual noises; the more powerful the noise the more danger there is of damaging the car.

CHAPTER V

SAFE DRIVING

THINGS TO REMEMBER

501. If you would be a safe driver remember these fundamentals:

502. Be fully alert; keep your eyes on the *whole* road *always*, and then:

503. Be twice as careful as you think you need be –have a margin of safety, and even then:

504. Whenever you are in doubt, choose the more conservative course.

505. Take no chances, and take nothing for granted. Don't be a dashing driver. New drivers should be especially careful. Avoid over-confidence.

506. Do not put too much confidence in your brakes. The best of brakes are likely to fail unexpectedly. Brake lining burns out, brake bands or shoes break, brake rods break, brake pedals or levers break, brake cross shafts come loose, nuts come loose, clevis pins drop out. On transmission brakes, the breaking of a shaft or key or the failure of bevel pinion or ring gear, or differential gears, will prevent the brake stopping the car. If a rear wheel slides out resting on the axle shaft, all rear brakes will be inoperative.

507. Anticipate the other fellow, and remember that he may not drive as he should. Don't insist on your rights when this course may cause you disaster.

508. Remember that we are all human and even the best intentioned drivers and pedestrians are likely to make mistakes. Also bear in mind that some are inexperienced, some are below average intelligence, and some have other disabilities. Do not forget that you can never count on what a child in your path will do.

509. Finally, be a pessimist. You should feel that you are next on accident's list if you break one of accident's rules. It is a trait of human nature to feel that the other fellow is the one who will have the hard luck. Many drivers never think of an accident resulting from their own carelessness—until THEY HAVE IT, AND THEN IT IS TOO LATE!

510. It is impossible to over emphasize the importance of putting yourself in the right frame of mind, if you wish to be a really safe driver. You must be a pessimist constantly looking for trouble. The average motorist, regardless of previous experience or ability, considers himself a safe driver, and he is, according to his lights, yet actually the average motorist rarely goes out on the road that he does not unwittingly set the stage for an accident, driving into crises that he should avoid. Fortunately, an accident does not occur every time the stage is set—far from it, but potentialities are there nevertheless, and it is the purpose of this chapter to show where the possibilities for accident lie so that they may be avoided.

511. Theoretically, the safe driver should possess abundant imagination, extensive experience, and be constantly on the alert, but fortunately where these qualities are lacking they may be cultivated.

512. The need for instruction in safe driving is particularly acute, because few drivers receive any instruction of this sort. What they learn about safety they usually pick up by experience. When they are first taught to drive, ordinarily, all they receive are the rudiments of gear shifting and steering; and their schooling is terminated before they become reasonably adept.

513. The beginner who has his mind fully occupied with the problem of manipulating control levers and pedals, has little time left for watching for even the few dangers that his limited experience shows him. Therefore it is highly important that beginners become reasonably skillful drivers as described in the two previous chapters before their instruction is considered complete. The beginner should be able to handle his car with confidence and without fear or nervousness before he is allowed to drive alone.

514. It must be stated, in the interest of all those who use the highways, that there are some people so unmechanically minded that they are incapable of becoming safe drivers, in fact, they never even learn to control a car properly. It must be emphasized, too, that backward beginners should receive extra instruction.

515. It is also true that not all people have the requisite strength to drive safely, even when they have all the other qualities. This is particularly true of people with weak or short arms or legs. A number of women fall within this class. Such people should limit themselves to cars with responsive steering gears, and easy acting brakes, and even then they should drive with more than ordinary caution. The length of some brake pedals may be adjusted to suit short legs, and others should be lengthened by whatever means are available. Sometimes a satisfactory remedy is to place a thick cushion at the back of the driver. A particularly dangerous combination is a short, slight woman behind the wheel of a car which has a stiff brake pedal and a stiff steering mechanism.

516. If it be assumed that the driver has the necessary physical strength and mental ability, it will be demonstrated in this chapter that safe driving is a matter of instruction. To emphasize the need for pessimism when behind the steering wheel it is helpful to classify all drivers under three heads, and briefly analyze their faults:

1. Most drivers wish to operate their cars safely, but frequently do not know how, lacking imagination, experience or both. As a rule, they do not realize their shortcomings.

2. Some drivers are indifferent, although they generally possess sufficient (unused) imagination and experience.
3. A few are reckless by nature.

517. Those in the third class are rarely reckless in their own minds, although they may enjoy being called reckless. They are generally overconfident, or too optimistic, or sometimes they enjoy playing to the grandstand even at the risk of their own necks or others. They particularly need to follow the instructions in the following sections.

USE OF STEERING GEAR

518. In avoiding accidents, the steering gear and brakes are approximately equal in importance. In most emergencies both must be used. Probably as many accidents are avoided by quick steering as by quick braking. Both steering gear and brakes should be in prime condition. Keep the front tires pumped and the steering gear thoroughly lubricated, and keep the brakes in adjustment. If either steering or brakes are below par, proceed at reduced speed. If the steering gear sticks or breaks so that the car can not be controlled, apply the brakes with sufficient force to lock the wheels (two or four) as this action usually forces the car to spin in a straight-ahead direction. Do not release the brakes until the car stops.

519. Most motorists do not realize how sharply a car running 25 miles an hour or more may be turned without tipping over. *Most* modern cars are sufficiently low so that they may be swung around a sharp right angle turn at 25 miles an hour without undue skidding and without danger of tipping. In fact, there is little danger of tipping at any speed, as long as the road surface is smooth and flat, although a disastrous skid is certain if anybody but an experienced racing driver attempts a right angle turn at 40 or 50 miles an hour. In making a sharp emergency turn at high speed the car is not likely to tip over unless the outside wheels skid into some obstruction, "stubbing its toe" and thus tipping. The obstruction might be a rut, a curbstone, or the like. Applicating the brakes in making a sharp turn at speed throws the weight of the car forward (more pronounced with 4-wheel brakes) and thus prevents the slipping or skidding of the front wheels, although the rear end may skid more or less, depending on the characteristics of the car, the "slippiness" of the road, and whether the rear wheels are locked or not. If the rear wheels are locked the rear end may change places with the front end. In fine, don't hesitate to turn a car sharply at 25 or 30 miles an hour if so doing is the only way to avoid an accident.

520. The foregoing emphasizes the point that for safety the steering wheel must be grasped firmly in both hands approximately as shown in Figure 50. In this position the hands have most powerful control of the wheel. All steering emergencies are met by this grip, and this position

should always be assumed when an emergency seems to be in the making, although other grips may be used to rest the driver. This grip should always be used in traffic and always when speeding. It is the only grip which gives complete and instant control of the steering wheel. Never drive with one hand when need for quick steering is imminent. Be prepared; have both hands on the wheel as shown.

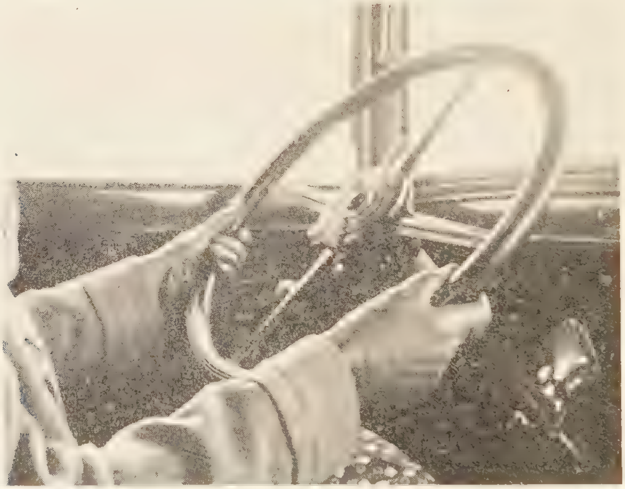


Figure 50.—The steering wheel must be grasped firmly with both hands

521. When an emergency seems near have the foot in readiness to apply to the brake pedal; in some cases it is advisable to remove the foot from the accelerator, allowing the car to coast, while the foot is placed temporarily on the brake ready for instant use.

522. When it seems likely that a crisis may arise, the driver should be well braced in his seat, and not slouched down as he may well be in driving along an open road. The driver should have both elbows free for instant movement. The left elbow should not be resting on the side of the car nor should the right elbow be impeded by the adjacent front seat passenger, as is frequently the case for one reason or another.

523. If brakes are below normal, or the tires do not grip the road surface with usual ability, the speed of the car should be curtailed accordingly. Remember that the quickest stop may be made on a clean, hard surface, and that less quick stops can be made on wet roads, dirt roads, dusty roads, muddy roads, gravel, sand, grass, oily roads, or roads covered with snow or ice. A car with a stiff steering gear must be handled more cautiously in traffic than

a car with a responsive gear. If steerage way is reduced, as when passing through a traffic lane with cars close by on either side, greatly reduced speed is desirable, because no dependence can be placed on the steering gear to avoid an accident.

USE OF BRAKES

524. Safe driving demands that the operator never outdrive his brakes. The operator, therefore, should know the ability of his brakes, if necessary testing them on various road surfaces at various speeds.

525. It will be apparent that the statement "never outdrive your brakes" applies regardless of the ability or condition of the brakes or the character of the road surface. It is admittedly an obvious statement, yet some of its applications are likely to be overlooked. Fundamentally, it means that the rate of speed should be so regulated that the brakes, as they are, will permit you to stop in time to avoid nearly any road crisis within view. It means that you should drive slowly in traffic; slow down at intersecting roads and streets; take turns and curves at reduced speed, blind ones especially; drive more or less slowly at night, depending on the power of your lights, and especially on rainy, snowy, or foggy nights. Curves and knolls on one-track country roads should be taken with especial care. It means also that when the character of the road surface reduces the braking ability, caution must accordingly be exercised.

FAMILIARITY BREEDS FORGETFULNESS

526. It is a curious fact that many drivers, ordinarily careful, develop an odd mental attitude toward natural difficulties fraught with danger. As an extreme case, they will drive at nearly their usual speed on a snowy night when the footing is treacherous and the windshield is half obscured by snow. They realize that it is difficult to see, that their stopping ability is reduced, yet they proceed as though they are not responsible for any damage which may occur. This attitude is difficult to explain, yet it is very human and all of us are more or less likely to fall into such error. Generally, it requires active and continued mental effort to avoid this state of mind. The worst of it is that it crops up at most unexpected moments. The glare of morning or evening sun in the eyes of the driver may blind him momentarily; yet how many of us slow down when this happens? And similarly, when blinded by bright lights at night. Because of this state of mind, slippery wet pavements, blinding reflections on the windshield, especially on a dirty windshield, and even railroad crossings are often ignored.

527. At the beginning of this chapter the reader was advised to be fully alert, yet this is not an easy precept to follow. Many of us are not naturally

alert; we fail to see a great many things within our view, and even the best of us are likely to have moments of unalertness. Inasmuch as no human being can be expected to be fully alert at all times, the only safe course is for everybody to drive with greater caution than would otherwise be necessary. Perhaps this thought is best summed up by the statement—be twice as careful as you think you need be; have a margin of safety.

528. If you will talk to drivers who have had accidents or if you will analyze your own mishaps, minor or otherwise, you will usually come to the conclusion that at some moment before the mishap you had your choice of two courses, and that choosing the less conservative course was the primary cause of the mishap.

529. You should form the habit of seeing everything on the road ahead, not only on the road itself but on sidewalks or paths at the side, and you should learn to anticipate the movements of everybody and everything. Remember that vehicles approaching intersecting streets, roads, or driveways are likely to turn into them; that pedestrians are likely to cross the street unexpectedly; and that children at play are likely to dash out at any moment. When in doubt slow down or stop as required. In this connection, remember also that many drivers break commonly accepted road rules; a few because they are indifferent, but most infractions are due to ignorance or absentmindedness. Be constantly on the alert for crises caused by such drivers.

530. If the throttle sticks open, as it may occasionally, apply the brake with the clutch in and shut off the ignition. Shutting off the ignition is sufficient, but applying the brake is more instinctive and therefore is likely to be done first. As a rule, the throttle may be freed by working the hand lever back and forth. Further sticking may be prevented by lubrication of the various joints in the throttle linkage. Sometimes the spring holding the throttle closed will break or break loose, in which case the throttle will not close when the pressure is removed from the accelerator pedal.

531. This chapter on safe driving is a suitable place to say a word regarding the hazard of engine exhaust. The exhaust gas of the average automobile contains 7 per cent of carbon monoxide, a gas that quickly overcomes anybody in a closed car outside or in a garage with the doors closed and engine running. Once overcome, a person is helpless and soon dies. Every year, particularly in winter, the newspapers record fatalities in the following style—a copy of a recent one:

Carbon Monoxide Gas Kills Man

Found Dead in Garage Early Today by Wife

Carbon-monoxide fumes caused the death of . . . . . , ... , in his garage early today. He had gone to get something from his car, his wife told the police. When he didn't come back to the house she went to look for him. He was lying on the floor and the motor of his car was going. Police and physicians worked over the unconscious man for nearly an hour, but were unable to revive him with a pulmotor.

Disregard of such warnings is common, but some day those who "know so much" may end in like manner.

Chapter VI

ENGINE REPAIRS

601. Many engine repairs are beyond the skill or tool equipment of the average automobile owner, therefore this section is confined to valve grinding, carbon removal, valve adjustment, valve timing, bearing adjustment, etc. It must be emphasized at once, however, that it is inadvisable for owners to attempt bearing adjustment, although the information is included for those who wish to use it. To a lesser extent valve grinding and carbon removal are also likely to prove to be unsatisfactory jobs in unskilled hands. It is sound advice, based on long observation, that the average man, even if mechanically inclined, should confine his efforts to the tightening of nuts and the making of minor adjustments; the more important jobs had best be left to a skilled man. Nevertheless, whether you make your own repairs or not, this chapter should be carefully read.

602. This is also a good place to emphasize the importance of care in removing parts—anywhere on the car. Always examine their structure carefully to be sure that removal of these parts will not damage other parts or allow them to slip out of place. Where there are similar parts be sure to put each part back in the place it came from. This holds in spite of the fact that similar automobile parts are "interchangeable." If necessary, mark the parts with a prick punch, pencil, chalk, or sketch them, to be sure that you put them back in the right relation; but be careful not to put any prick punch marks on wearing surfaces or other close-fitting surfaces; punch marks should only be placed on "free" surfaces. Be careful to clean all parts with kerosene before returning them, and lubricate all wearing surfaces with oil. In reassembling parts be careful not to get grit on wearing surfaces. Tighten all nuts carefully and do not fail to insert cotter-pins and lock-washers as required. Where there is more than one washer on a shaft be sure to observe their arrangement before removing them so that they may be replaced in correct relation.

603. Valve grinding and carbon removal are often mentioned together partly because the two are likely to be necessary at the same time, and partly because in modern engines it is usually necessary to remove the cylinder head to do either one, and once the head is off, both jobs are done, even though one may be only slightly needed.

CARBON DEPOSITION AND PREVENTION

504. Carbon accumulates on cylinder and piston head, and when sufficient is present a carbon knock is heard; if the carbon deposit is heavy the engine may run for a few revolutions after the ignition switch is turned off, and in an extreme case overheating will occur. Some loss of power will be noted as the carbon accumulation increases.

605. Part of the deposit is formed by charred lubricating oil, part by incomplete combustion due to an over-rich mixture, and part by road dust. The latter, of course, is not carbon. As the combustion chamber may reach a temperature of 3,000° at the moment of explosion, it is clear that any lubricating oil may char more or less, but a high-quality oil will char less than a low-quality oil and, curiously a light oil exposed to this heat will char less than a heavy one. Further, if for any reason the combustion chamber receives an excessive amount of oil (as with worn piston rings) more charring will occur than if it obtains just the right amount. Carbon deposit due to oil is minimized in a given engine by having the lubricating system working properly and using the brand of oil recommended by the manufacturer of your car or by some leading lubricant manufacturer.

606. Gasoline is composed of hydrogen and carbon, and when these unite with the oxygen in the air (burn), it is found that hydrogen has a stronger affinity for oxygen than carbon has. Therefore, if there is not enough air to go round, some of the carbon particles will be unable to find oxygen mates. Some of this free carbon sticks to the combustion chamber walls. Carbon may be formed in this way either because the carburetor adjustment provides too much gasoline in proportion to the air or because the fuel is not thoroughly vaporized and mixed with the air; in the latter case the mixture at the moment of combustion is not homogeneous, being rich in some spots and weak in others.

607. Carbon deposit from incomplete combustion may be minimized by obtaining a proper carburetor adjustment, especially an adjustment that is a trifle lean, plus adequate heating of the mixture, which means, for example, that the mixture-heating device must be in good working order. Carbon deposit due to road dust may be practically eliminated by the installation of an air cleaner.

608. It will be seen that by the use of an air cleaner, good engine oil changed frequently, and a proper mixture, carbon deposit may be minimized. The sensitiveness of an engine to carbon may be reduced by the proper choice of combustion chamber form, a well known example being the Ricardo type combustion chamber (Figure 51).

609. A carbon knock causes a loss of power and an increase in fuel consumption, proportional to its intensity; otherwise it does no harm. The knock may be stopped and carbon removal postponed by the use of a good high

compression fuel. As a rule a carbon knock is a sharp metallic noise heard on wide open throttle, but disappears when the throttle is closed or the spark is retarded. No distinction can be made between carbon knock and spark knock, except to say that if an engine perfectly free of carbon knocks, either the spark is advanced too far, or the compression is too high or the fuel is of poor quality. If the spark advance is correct, too high compression is probable, and compression may be reduced by installing two cylinder-head gaskets in place of one.

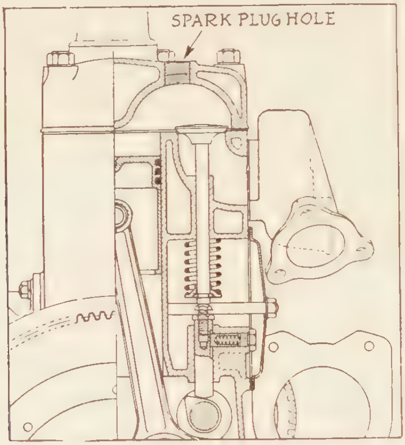


Figure 51.—Dome shape of Ricardo combustion chamber

610. If carbon is indicated its presence may often be determined by removing a spark-plug and examining the interior of the engine. A heavy carbon deposit may also be found on the spark-plug. If the interior of the engine looks or feels somewhat like charred grease on a pancake griddle, carbon removal is required.

VALVE GRINDING

611. Generally, however, carbon removal may be postponed until valve grinding is required. The need for valve grinding is largely due to the presence of carbon in the cylinder. Small particles of carbon settle on the faces of the exhaust valves, preventing full closing and allowing hot exhaust gases to leak through the slight openings. The hot gases burn pits in the valves and the carbon accumulation increases at the same time. Therefore, assuming that the valves were tight in the first place, the need for grinding is usually indirectly caused by carbon. Carbon accumulation on the valve faces may be minimized by allowing more than the usual clearance between exhaust valve stem and push rod, because the greater the clearance the greater

the pounding of the valve face against its seat and therefore the harder it is for carbon to lodge. On the other hand, if the clearance is absent, full closing of the valve will be prevented and carbon accumulation and pitting will begin at once. Leakage is less likely if the valve stems are reasonably tight fits in their guides, because this facilitates tight seating of the valves. Worn valve stems and guides may necessitate frequent valve grinding.

612. It is mainly the exhaust valves that require grinding, although intake valves require touching up now and then. The more the exhaust valves are neglected the greater the leakage, and in an extreme case the valve may actually be half burned away by the hot gases streaming past it before it is attended to. A badly leaking exhaust valve may stick due to the heat warping the valve stem.

613. Need for valve grinding is indicated by loss of power, hard starting, increase in fuel consumption, missing at slow speed, and perhaps knocking if the valve is extremely leaky. Leaky intake valves will always be accompanied by backfiring in the carburetor.

614. Every 3,000 miles or so the compression of the engine should be tested, and if any cylinder is notably weak and yet the valves are properly adjusted, valve grinding is necessary (see paragraph 638). If weak compression is caused by leaky piston rings the spark-plug will probably be fouled with oil, the engine missing on this cylinder, whereas a dry spark-plug (probably with regular firing of this cylinder except at low speed) indicates a leaky exhaust valve if the compression is weak. A leaky intake valve will be accompanied by backfiring.

615. If valves leak the engine will run irregularly at low speed (5 m.p.h.) on open throttle. Thus if the engine runs evenly on this test it shows the valves are tight. A more accurate test is to crank the engine by hand. Each cylinder in turn should offer a "springy" resistance if valves are tight. Whereas if this resistance is lacking the valves leak in this cylinder.

616. As a rule, the owner's work should stop here. If the need for valve grinding and carbon removal has been determined, he should have his findings checked by his repairman, allowing the latter to do the work. However, if the owner wishes to proceed, the method is described below.

617. Most modern cars have a detachable cylinder head necessitating the removal of this member both for valve grinding and carbon removal.

HOW TO REMOVE A CYLINDER HEAD

618. Drain radiator (if filled with anti-freeze, save it); detach upper hose connection; in some cars it is necessary to loosen radiator at bottom to do this; remove cylinder head nuts (a socket wrench is often required); crank engine by hand for a few revolutions to loosen cylinder head from gasket; if this is not successful, pry cylinder head loose with screw driver or similar

tool; lift off cylinder head carefully, being careful not to drop it, as it is brittle. In some cars it is necessary to loosen intake and exhaust pipes, remove carburetor and other fittings before head may be removed.

SCRAPING CARBON

619. With a blunt, flexible tool such as a small putty knife, scrape clean the entire surface of the combustion chamber. If all particles of carbon are not removed carbon will accumulate rapidly on these spots, necessitating scraping again in a short time. The piston head may be most conveniently reached by turning the engine until it is approximately on top dead center. Clean all carbon from the spark plugs; better remove them to do a good job, setting up the points at the same time.

620. On engines not provided with a removable head it may be necessary to remove the cylinders to scrape out the carbon, although in these it is usual to burn the carbon out with oxygen, but inasmuch as no motorist is likely to have oxygen available, this method will not be described. There are other methods of removing carbon, but their use is so rare that it is not worth while describing them.

621. All loose carbon particles should be removed from the combustion chamber by means of a whisk broom, oily rag, or compressed air; the air supplied by a foot pump is sufficient.

VALVE REMOVAL

622. It is generally more convenient to remove the valves before scraping the carbon, as they are somewhat in the way.

623. Valves are ordinarily arranged at the side of the cylinder (Figures 4 and 6), or overhead (Figure 7). The former is spoken of as an L-head cylinder because the combustion chamber resembles an L inverted, and the latter is similarly called an I-head cylinder, although it is more usual to describe the engine as having overhead valves. Figure 2 shows a T-head engine. In most overhead valve engines the camshaft is in the same position as in L-head engines, the valves being actuated by long valve rods and rocker arms, although in a few the camshaft is placed on top of the cylinders.

624. If the engine does not have a detachable head, in the case of L- and T-head cylinders, valve caps or plugs are screwed into the cylinder directly above each valve (Figure 2). After the removal of these caps the valves may be withdrawn. In a few cars equipped with overhead valves in integral cylinder heads it is necessary to remove the cylinders to remove the valves, but it is more usual when overhead valves are used with an integral cylinder head to place the valves in cages, Figure 54, so that the valve and its seat may be removed as a unit and ground at the bench.

625. Valves are usually held in place by a locking pin at the base of the spring (Figure 52, *A*), or by a U-shaped washer which fits into a groove in the valve stem (Figure 52, *B*). In either case the first step in removing the valve is to compress the spring so that the locking device may be withdrawn. There are many cheap and simple tools which may be purchased in accessory stores for compressing valve springs. On some small engines they may be compressed with the fingers, depending more or less on the strength of the individual, and springs on overhead valve engines may be compressed by placing an open-end wrench on the valve spring seat and pressing on it after the head has been removed. This method is not always feasible on L- and T-head engines because of the cramped working quarters.

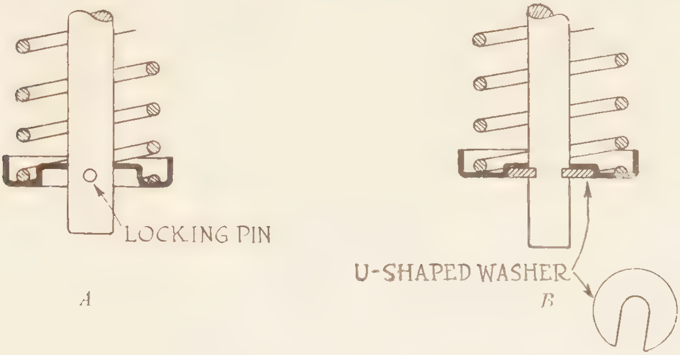


Figure 52.—Two common methods of retaining valve springs

626. After the locking device has been removed from all valves, remove the valves, on L- and T-head engines, by prying up on the valve stem with a screwdriver until the head of the valve can be grasped in the fingers. This operation is sometimes facilitated by lassoing the head of the valve with a fine string or wire. In an overhead valve engine it is convenient to remove the springs before removing the valves, but in an L- or T-head engine the springs must be pulled out forcefully with the fingers after the valves have been removed. For convenience, valves partly open should be closed by cranking the engine through one revolution before any attempt is made to remove them.

627. On overhead valve engines the valve assembly generally lifts off with the head without the necessity of taking special steps to detach it. Inasmuch as the rocker arms are usually in the way for valve removal and valve grinding it is often desirable to remove the rocker arm mechanism as a unit before working on the valves.

628. As you lift the valves out one by one be careful to place them in a row so that you will grind each valve in its own seat. Frequently, a better plan is to remove and grind the valves one by one. As each valve is removed, examine its face and its seat in the cylinder. The intake valves will require little if any grinding, but if face and seat are not reasonably smooth and clean a little grinding will be required.

629. The exhaust valve faces and seats will generally be found to be more or less pitted and encrusted with carbon. The carbon should be scraped off of face and seat with a knife, and all carbon should be removed from the valve stem, as carbon on the stem is likely to interfere with the closing of the valve and may cause its sticking open. If exhaust valve stems are badly burned where they contact with their guides, new valves with oversize stems, or new valves with new guides (choice depends on engine construction) may be required. In either case, only an experienced repairman should do the job.

630. After the valves and their stems have been thoroughly cleaned of carbon, apply a little coarse grinding compound to the face of the valve, being careful not to get any compound on the valve stem. Valve-grinding compound may be purchased at any accessory store, and is usually supplied in a small double-ended can, coarse compound on one side and fine on the other.

631. Insert the valve in its own seat in the cylinder. If the valve is "open" crank the engine through one revolution; there must be clearance between the valve stem and the push rod. Insert a screwdriver in the slot in the head of the valve, or a specially forked tool if the head of the valve is provided with two holes. Oscillate the valve back and forth about 25 times through a half revolution, being sure to exert a vertical pressure and not a side thrust, pressing just enough to cause the compound to "bite." Then lift the valve and rotate it through a part of a revolution, and oscillate it again. Repeat this process and examine the valve surfaces now and then, until the valve not only makes a continuous line of contact with the seat, but until all large pit holes are reduced to negligible size. It is not necessary to remove completely all vestige of pit-holes. Then smooth the valve face and seat by grinding with fine compound. When the job is finished be sure to wipe off every trace of compound, and wipe off any compound which has accidentally adhered to the cylinder walls. If during the process any compound has been accidentally applied to the valve stem, clean it carefully, and also draw a clean rag moistened with gasoline through the valve stem guide.

632. The only way to be sure of a perfect valve grinding job is to re-face valve faces and seats with special cutters made for this purpose, followed by grinding the valves lightly into their seats. Inasmuch as the average owner does not possess these tools, a home valve-grinding job is not always successful, although with patience shoulders may be dressed off with a fine file. After valves have seen some service the valve face is likely to be grooved

(Figure 53), where it pounds against its seat, and the "shoulders" thus formed on the valve face in combination with side play in the valve due to wear of valve stem and guide may prevent the valve from closing tightly every time. The grooves in the valve face, of course, are made deeper by continued grinding without re-facing, and this aggravates the situation. The consequence is that the greater the side play the greater is the need for re-facing. If side play is excessive in combination with deep grooves, valve leakage may be so great that the engine may all but refuse to start, and once started will develop little power with much missing, and excessive backfiring if the intake valves are at fault. The remedy is to have the valve guides reamed out and new valves with larger sized stems fitted, or to have new valve guides and new valves installed, the latter being the thing to do if the valve stem guides are removable. New valves may be essential after 15,000 miles or more, depending on the engine and the care it receives. The need for frequent valve grinding is often due to valves which seat badly from side play in the valve stems, and from this standpoint new valves may be an economy. With well-fitting valve stems, a good job of valve grinding in the first place, plus good engine oil frequently changed, plus correct valve adjustment (not too tight), valve grinding should rarely be required oftener than once in 10,000 miles; some makers claim 25,000 miles for their product—with justice, the writer believes.

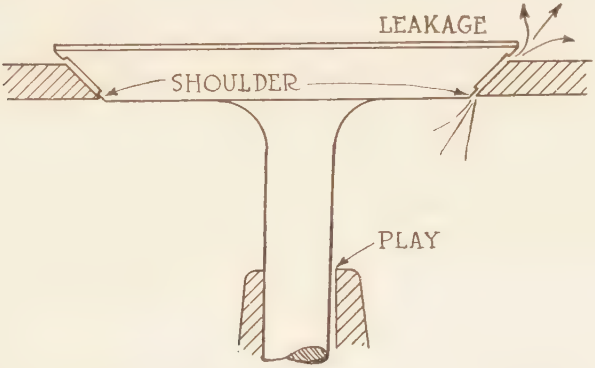


Figure 53.—How shoulders on a valve may cause leakage

VALVE REPLACEMENT

633. Replacement of the valves is obviously the reverse of removing them. Put the valve spring in place, insert the valve, compress the spring and insert the spring lock. Lubricate each valve stem with a few drops of oil.

CYLINDER-HEAD REPLACEMENT

634. Before replacing the cylinder head it is advisable to procure a new cylinder-head gasket. The old gasket is likely to leak and the cost of a new gasket compared with the risk of having to remove the head again is so small that it is nearly universal practice to put on a new gasket whenever the head is removed. Remove the old gasket and clean the face of the cylinder and cylinder head thoroughly, scraping them with a knife or similar tool, as any particles remaining on the surface may cause leakage. It is customary to coat both faces of the gasket with shellac or cup grease, but in either case be careful not to put on too much or it may squeeze out into the cylinders after the head is applied. The heat in the cylinder will burn the material to carbon with the result that a carbon knock may develop at once.

635. The gasket should be carefully worked down over the cylinder head studs until it lies flat against the top of the cylinder, and then the head should be put on. Put on the cylinder-head nuts and run them down finger tight. Then tighten the nuts gradually with a wrench. Draw up the center nuts a little first and then work by alternate progression toward each end. After all nuts are somewhat tight, repeat the process, drawing them still tighter. Then go over them again. Generally speaking, any nut may be considered tight when it refuses to move under a sharp but moderate pull.

636. In attaching the cylinder head as well as in attaching any other parts removed, be careful to reverse exactly the order of disassembly. If this rule is not followed it may be necessary to remove some parts already attached to put others in place.

637. When all parts have been reassembled, fill the radiator, and run the engine at a moderate speed until it is thoroughly warm. Then tighten all cylinder-head nuts. It is also good practice to test the tightness of the nuts after running the car a hundred miles or so.

VALVE ADJUSTMENT

638. After the engine is warm the valves should be adjusted. In overhead valve engines it is most essential to have the head fully tight before adjusting the valves, as tightening the head reduces the valve clearance. Grinding valves obviously reduces the clearance between valve stem and push rod, because the valve is "tunneled" more deeply into its seat. On L- and T-head engines the point of adjustment is shown in Figure 4. The lower nut is always the lock-nut and the upper one is turned to adjust the clearance, after which the lower nut is drawn tight to lock the adjustment. By turning the upper nut to the right the clearance is increased. If the push rod is rotatable in its guide it must be held by a wrench while the lock-nut is being loosened or tightened, although it is usually sufficient to hold it with the

fingers when turning the upper nut. Two small end wrenches which exactly fit these nuts are desirable.

639. Before adjusting a valve it is necessary to be sure that the valve is fully closed. One simple method is to watch the closing of the intake valve on the particular cylinder, and then turn the engine through half a revolution after this valve is closed. Both intake and exhaust valves on this cylinder

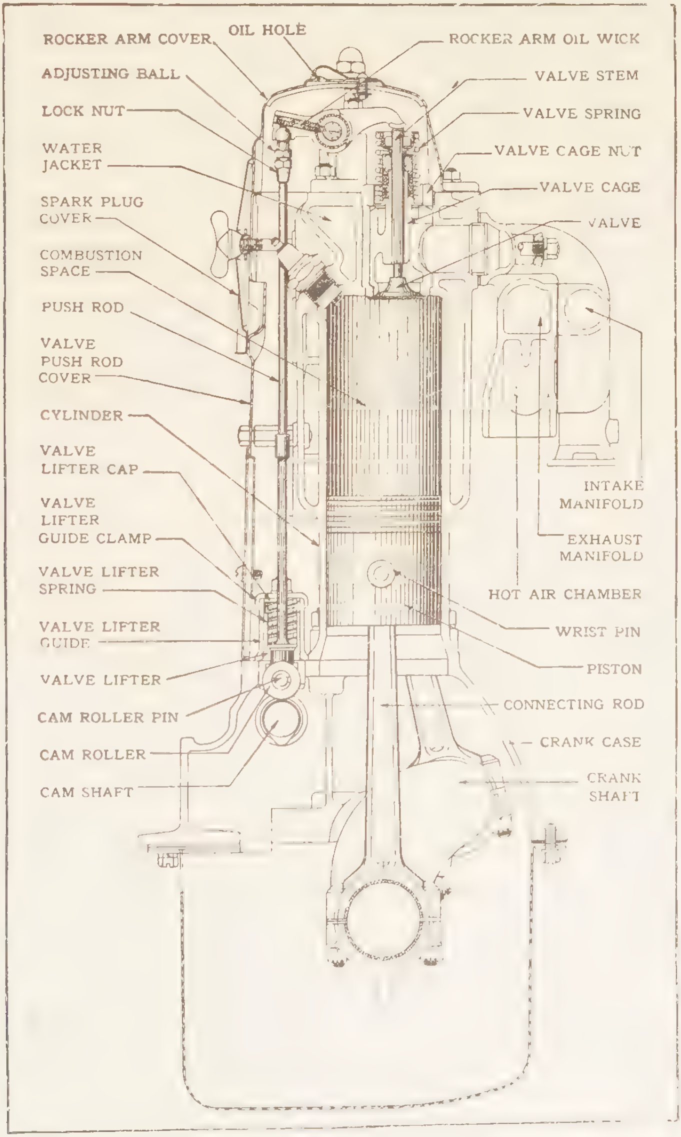

ROCKER ARM COVER
OIL HOLE
ROCKER ARM OIL WICK
ADJUSTING BALL
VALVE STEM
LOCK NUT
VALVE SPRING
WATER JACKET
VALVE CAGE NUT
VALVE CAGE
SPARK PLUG COVER
VALVE
COMBUSTION SPACE
PUSH ROD
VALVE PUSH ROD COVER
CYLINDER
VALVE LIFTER CAP
INTAKE MANIFOLD
VALVE LIFTER GUIDE CLAMP
EXHAUST MANIFOLD
VALVE LIFTER SPRING
HOT AIR CHAMBER
WRIST PIN
VALVE LIFTER GUIDE
PISTON
VALVE LIFTER
CONNECTING ROD
CAM ROLLER PIN
CRANK CASE
CAM ROLLER
CRANK SHAFT
CAM SHAFT

Figure 54.—Buick (1923) six-cylinder engine with valves in cages

may then be adjusted. Often you can determine which is the intake valve by examining the branching of the exhaust pipe or by the position of the spark-plugs. The spark-plug in an L-head cylinder, if *direct over* a valve, is always placed over the intake valve.

640. Otherwise use this method: Remove the cover to the distributor and note to which segment the distributor arm is pointing. Trace the high-tension wire connected to this segment to a spark-plug. Adjust the valves on the cylinder in which this spark-plug lies. Turn the engine through a part of a revolution until the distributor brush points to the next segment. Trace the high-tension wire connected to this segment to its spark-plug. Adjust the valves of this cylinder, and so on. The amount to turn the engine depends on the number of cylinders, one-half revolution on a four, one-third revolution on a six, one-quarter revolution on an eight, one-sixth revolution on a twelve.

641. The correct clearance between valve stem and push rod varies with different engines, but the important point is to have enough clearance so that there will always be some clearance, regardless of how engine parts expand or contract under heat and cold. And a little more than a minimum clearance is advisable to secure some pounding of the valve against its seat, although the greater the clearance the more the noise. Too much clearance also reduces the time that the valve is open, which is a disadvantage. A good general rule is to make the clearance two to three times the thickness of this paper. A little experience in valve adjusting will indicate when clearance is correct or excessive simply by sense of touch as ascertained by moving the push rod up and down.

642. After the correct clearance is obtained the lock-nut should be drawn tight, then the clearance should be tested again as tightening the lock-nut may change the clearance, in which case, due allowance in adjustment must be made for the lock-nut.

643. Overhead valve engines usually have the adjustment on the long valve rod which connects the rocker arm to the push rod (Figure 54), although sometimes the adjustment is placed at the center of the rocker or at the end of the rocker where it touches the valve stem. The method of adjustment is similar to that described for L- and T-head engines.

VALVE CARE

644. It is a good practice to check the valve adjustment from time to time, as it only takes a moment and often reveals engine trouble in the making. If it be assumed that the valve clearance is correct in the first place, and the lock-nuts have not worked loose, a gradual increasing clearance indicates increasing need for valve grinding, and excessive clearance indicates a valve with carbon on its stem, the result will be burning or warping of the valve

if it is not attended to. Excessive clearance may be accompanied by missing except at high speed with throttle wide open.

645. Leakage past an intake will cause backfiring. This may be due to excessive clearance (failure of the valve to close fully for any reason), or to absence of clearance due to valve adjustment being too tight.

646. In an overhead valve engine, increasing clearance may be due to wear of rocker arms, or to loosening of the mechanism which supports the rocker arms. In this case the symptoms may be loss of power, missing; or almost imperceptible *backfiring* into the carburetor with excessive clearance on an *exhaust* valve.

647. If a valve badly in need of adjustment is found, do not adjust it unless the lock-nut is loose, if you are positive that the adjustment *was* correct some time before. The need for adjustment may be need for grinding, or carbon on valve stem, or stuck valve, or worn rockers, or loose rocker merchanism.

648. A stuck intake valve will cause backfiring and a stuck exhaust valve will cause missing, accompanied by more or less tapping or light, metallic knocking—caused by excessive clearance. Pull or pry the valve loose and lubricate it with engine oil, or half-in-half mixture of oil and kerosense. If it sticks repeatedly remove it. Sticking may be caused by warping produced by overheating caused by excessive leakage (exhaust valves only). This also may occur in a new car or one with new valves that are a trifle too tight, sticking appearing occasionally with a hot engine. Valves that are too tight will wear loose when assisted with a little oil.

649. All valve mechanism wearing surfaces require lubrication. Valve stems are generally lubricated by oil vapor and the rocker arms on some cars are also lubricated in this way, although most overhead valve engines are now lubricated by pressure feed. There are many engines in use, however, which require frequent lubrication of rocker mechanism with oil and grease; oil for the oil holes and grease for the grease cups. Rapid wear will result if the lubrication of the overhead valve mechanism is neglected; L- and T-head valve mechanisms need no attention. Worn rocker-arm parts should be renewed when they are noisy.

650. Worn push rods and push-rod guides are not likely to exert a harmful influence on the engine performance except that they may eventually become objectionably noisy. New push rods and guides may be readily installed, although if the push-rod guides are integral, they must be reamed and fitted with over-size push rods. A valve with too much clearance will produce a tapping noise.

651. Engines not equipped with poppet valves do not require valve grinding, and this statement includes Knight sleeve-valve engines. These engines also rarely if ever require removal of the carbon.

652. Weak or broken valve springs are rare. A weak valve spring is

indicated by missing at high speed, the missing probably disappearing when the coils in the spring are spread with a screwdriver. The spring should be replaced. A broken valve spring causes missing, often accompanied by a tapping or knocking. The broken spring should be replaced as soon as possible, even though it is necessary to put in a spring from some other make car temporarily. It is not necessary to remove the cylinder head to replace a valve spring. The spring may also be repaired by cutting a disc of metal about 1/16 inch thick and slightly larger than the diameter of the spring. A hole is bored in the center slightly larger than the valve stem, the disc being placed on the valve stem between the two broken pieces of the spring.

653. Pronounced missing is always a strain on the car mechanism, but no additional harm occurs in operating a car with a broken valve spring unless there is danger of the valve dropping into the cylinder (overhead valve engines only). If the broken spring greatly interferes with the closing of the valve, better engine operation is sometimes secured by cutting the valve out, as by slacking off completely on the valve adjustment or by removing the valve rod (in an overhead valve engine) or the push rod.

VALVE TIMING

654. The motorist who wishes to diagnose his engine troubles should know how to check the correctness of the valve timing, which means the time of opening and closing of the valves with reference to the up-and-down movement of the pistons. For the purpose of this book it is sufficiently accurate to say that the intake valve opens approximately at the beginning of the suction stroke; in other words, when the piston is at top dead center or perhaps ⅛ inch on its suction stroke. The intake valve closes when the piston has already traveled about ½ inch on the compression stroke. The exhaust valve opens about ½ inch from the bottom of the explosion stroke, and closes at about the end of the exhaust stroke; at top center. On most cars, correct spark timing indicates correct valve timing.

655. Valve timing marks will usually be found on the flywheel, but if these are missing, incorrect, or difficult to interpret, it may be assumed with fair accuracy that the exhaust valve should just be closed when the piston is at top dead center. It is easiest to determine top dead center with the cylinder head off, but it is not generally worth the trouble to remove it, because an approximate determination may be made by feeling the upward movement of the piston with a stiff wire inserted through a spark-plug hole.

656. If the exhaust valve closes when the piston is at top dead center the valve timing is probably correct.

657. If the flywheel is marked, as is common, it is preferable to check the valve timing with the marks on the flywheel. As a rule, these marks register with a pointer (Figure 55), although to observe them it may be necessary to

remove a hand-hole cover which is generally in the flywheel housing. The marks are indicated in various intelligible ways, such as, *E. C. 1 and 4,* which means that when this mark on the flywheel is exactly under the arrow point, either the exhaust valve on cylinder *1* or *4* should be just closed. On engines with one camshaft, all the valves must be correctly timed if one is. Therefore, if it is found that the exhaust valve in cylinder *1* closes on the mark the engine is correctly timed. The valves must be adjusted to correct clearance, as described before checking the valve timing. Unless the valves have just been ground, an intake valve only should be used in checking timing; never an exhaust valve.

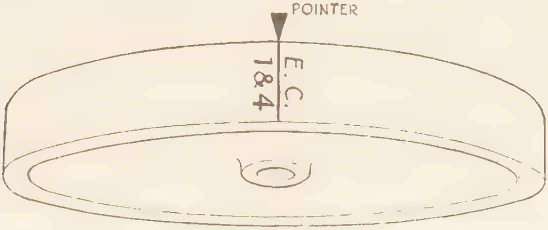


Figure 55.—Typical valve-timing marks on flywheel

658. Knight engines may be checked by removing intake or exhaust pipe and observing the opening of the sleeves.

CHAIN ADJUSTMENT

659. The necessity for checking valve timing is mainly due to the use of silent chains instead of gears for driving the camshaft and other units from the crankshaft; the majority of cars today, except those of lowest price, have this construction. If the adjustment of the timing chain is neglected the chain may eventually become so loose that it slips a cog or two, with resultant loss of power and other troubles; whereas if the chain slips sufficiently the engine may suddenly refuse to run. When everything about the engine is in good order, loss of power or failure to run may be due to incorrect valve timing.

660. Some silent chains require no adjustment; but the majority of chains need adjusting at the end of about 1,500 miles to take up initial wear, and again at about 10,000, 20,000 miles or more, although the figure varies greatly with different cars and the care they receive. The point, however, is that the motorist should have his repairman check the chain adjustment every few thousand miles.

661. Chain adjustment is a big subject and should be left to a competent repairman. However, those who wish to do this work themselves should first

find the means for chain adjustment; it varies greatly in different cars and is not always easy to find. If the generator is mounted direct on the timing gear case and if the screws or studs attached to its flange base work in slots, pulling the generator toward you after loosening the nuts which hold the base will tighten the chain; although if the generator is gear-driven the generator is *pushed in* to obtain correct gear adjustment. If the generator is at the side of the crankcase and is driven through a coupling, the chain adjustment is likely to be an eccentric directly forward of the coupling, adjustment being effected by rotating the eccentric after removing the locking device.

662. The most satisfactory method of obtaining a fine chain adjustment is also the least known. Remove the cover plate in front of the generator sprocket or the plug above; almost invariably one or the other will be found. With the engine stopped, tighten the chain adjustment until the chain is too tight to be moved back and forth slightly *across* the teeth of the sprocket (lengthwise of the car) with the fingers. Then slack off just enough so that the fingers can move the chain as described. If the directions are correctly followed, this adjustment will be found to be perfect.

ENGINE BEARINGS

663. Every 5,000 or 10,000 miles it is advisable to have a repairman run your car to determine if main or connecting-rod bearings need attention, or you may make the test yourself as described in paragraph 1575. It is not advisable to run your engine until a serious knock develops. If your bearings wear gradually and uniformly a noisy engine may indicate bearings that are becoming too loose. If a bearing becomes much too loose, serious damage may result.

664. As previously stated, bearing adjustment should be done only by a skilled mechanic, but the following instructions may be followed if a home job is desired: The play between bearing and crankshaft should not be more than 0.003 inch for a pressure-lubricated engine, nor more than 0.015 for a splash-lubricated engine, although figures vary somewhat with different engines.

665. Plain bearings, as distinguished from ball and roller bearings, if adjustable are usually made in halves; whereas non-adjustable plain bearings are generally made in one piece, the latter frequently being called bushings. Main and connecting-rod bearings may or may not be adjustable; if non-adjustable, they must be replaced when worn.

666. If these bearings are adjustable, adjustment is secured either by filing, or by rubbing the face of the bearing cap on a piece of fine emery cloth laid on a flat surface, until enough material has been removed to adjust the bearing properly. This treatment is not necessary if the bearing cap is pro-

vided with shims, which are thin strips of metal and the bearing is adjusted by removing some of them. The same number and thickness of shims should be removed from each side of the bearing cap. A connecting-rod bearing may be considered correctly adjusted when it is too tight to be moved slightly endwise of the crankshaft with the fingers, but not so tight that it may be moved when gently tapped with a hammer. A main bearing may be considered correctly adjusted when some additional effort is required to turn the engine over, yet not enough to prevent cranking by hand. Slack off each main bearing after adjusting so that the next one may be tested accurately.

667. Badly worn bearings may require scraping or replacement; scraping is often necessary after replacement. Scraping tools are required for this work. The bearings cap is removed, the crankshaft journal is smeared lightly with Prussian blue, the bearing cap is bolted in place and the crankshaft rotated through a few revolutions, thus bluring the high spots on the bearing surface. The bearing cap is removed and connecting-rod and piston are withdrawn. The blue high spots are scraped off and the connecting-rod is put back on the shaft, drawn tight, the crankshaft rotated, and a new set of blue high spots obtained. These are scraped off and so on until the high spots are small and evenly distributed. Main bearings may be scraped in a similar fashion. Oil the bearing surface before final tightening. On most modern engines bearing scraping is unnecessary. In cases when bearings become badly worn they should be replaced by new bearings which are so accurately made that fitting is not required.

OIL-PAN REMOVAL

668. To adjust the bearings or to examine them it is usually necessary to remove the bottom half of the crankcase, or oil pan, and if the work is carefully done it may not be necessary to drain the oil from the pan, although generally it is considered more convenient to do so. The pan may be removed as soon as the various screws in its flanges are removed. In replacing the pan be sure that its gasket is in good condition. If the gasket is badly torn or worn it should be replaced. Shellac one side of the gasket to hold it securely to the flange. Smooth out all wrinkles and be sure that the flange surfaces are clean. Oil leakage is likely if the gasket is not perfect and perfectly applied.

669. Sometimes, to remove the piston and connecting rod through the crankcase, it is necessary to turn the crankshaft as the process of removal proceeds. In replacing a piston be careful not to push it too far up into the cylinder, as the top ring may catch in a shoulder at the top of the cylinder bore.

WEAR AND FIT OF PISTONS, CYLINDERS, AND RINGS

670. The pistons must be a good fit in their cylinders and pistons and cylinders must be smooth and round. The piston rings must also meet these requirements. The rings must have strength enough to press rather firmly against the cylinder walls. If all these conditions are satisfied, the rings prevent the leakage of more than a small amount of gas from the combustion chamber into the crankcase, and also minimize the leakage of oil from the crankcase to the combustion chamber. Worn cylinders and pistons and leaky rings will cause loss of power and high oil consumption simultaneously.

671. Wear of cylinders, pistons, and rings is minimized by proper lubrication, which means the use of good oil changed frequently. New piston rings may be required after 10,000 miles up, depending on conditions. If engine lubrication fails, or if the engine is run without water, new rings may be required as soon as the damage is done, regardless of how new or old the car is. Sometimes the defect will apply to only one cylinder, probably with the result that this cylinder will receive so much oil that the spark-plug will foul repeatedly, the cylinder missing whenever this happens.

672. As a rule, faulty piston rings are indicated by excessive oil consumption often accompanied by a blue exhaust, with some reduction in power. Spark-plugs may or may not foul readily with oil. Blue smoke and fouled spark-plugs may also be caused by too light an oil or some defect in the lubricating system which allows too much oil to reach the cylinders.

673. New piston rings alone are of little benefit if cylinders and pistons are badly worn. Generally, after an engine has worn out its second set of rings, which may happen after 20,000 to 60,000 miles, the cylinders must be refinished and oversize pistons fitted. Cylinders may be refinished by grinding, reaming, honing, or boring. Methods which do not involve the removal of the engine from the car are least expensive and usually quite satisfactory.

674. Whether it is advisable to fit new pistons without refinishing the cylinders is a question for a repairman to decide.

Chapter VII

ENGINE LUBRICATION

701. There is only one sure way to obtain good oil: Buy it in sealed cans from a reputable manufacturer. The best oil is the most economical in the long run. You should not only obtain a first quality oil but consult a lubricant manufacturer regarding the type of oil best suited to your engine. Don't assume that medium oil is best for all machines. There are no simple tests for determining a good oil. Automobile engine lubricating systems are broadly divided into two classes—pressure and splash. In both systems it is common to employ the bottom half of the crankcase as an oil reservoir.

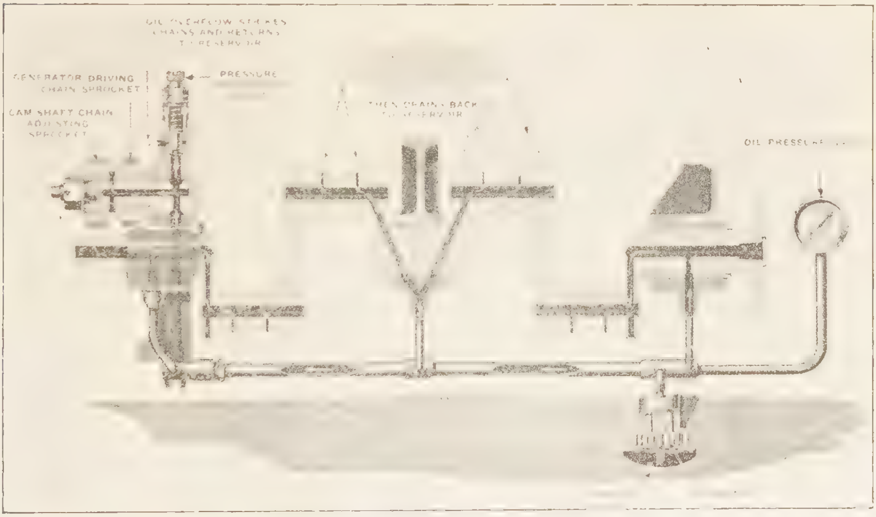

OIL OVERFLOW STRIKES CHAINS AND RETURNS TO RESERVOIR
GENERATOR DRIVING CHAIN SPROCKET
PRESSURE
CAM SHAFT CHAIN ADJUSTING SPROCKET
THEN DRAINS BACK TO RESERVOIR
OIL PRESSURE

Figure 56.—Pressure lubricating system

PRESSURE SYSTEM

702. In the pressure system (Figure 56), a pump draws oil from the reservoir and delivers it under pressure to the main and connecting-rod bearings; other engine bearings including camshaft and wristpin bearings may also be lubricated by pressure or may be lubricated by oil spray and mist thrown from the main and connecting-rod bearings. Pistons, cylinders, and

piston rings are always lubricated by spray. The pump first delivers oil to the main bearings, whence it passes through holes drilled in the crankshaft to the connecting-rod bearings. The system usually includes a pressure relief valve which prevents the oil pressure from rising beyond a certain value as the engine is speeded up. The relief valve may be adjusted to increase or decrease maximum pressure, and in this way the quantity of oil which the cylinders, pistons, and rings receive may be varied, because the greater the pressure the more spray and mist is created by leakage from the crankshaft bearings.

SPLASH SYSTEM

703. In the splash system all parts are lubricated by spray and mist created by the splashing of the connecting-rod scuppers into the splash troughs (Figure 57). A scupper is a short projection on the lower end of the connecting rod. The troughs are kept full of oil by the pump, which draws its supply from the oil reservoir. Oil which overflows from the troughs, as well as oil which trickles down the interior of the engine, drains into the oil reservoir.

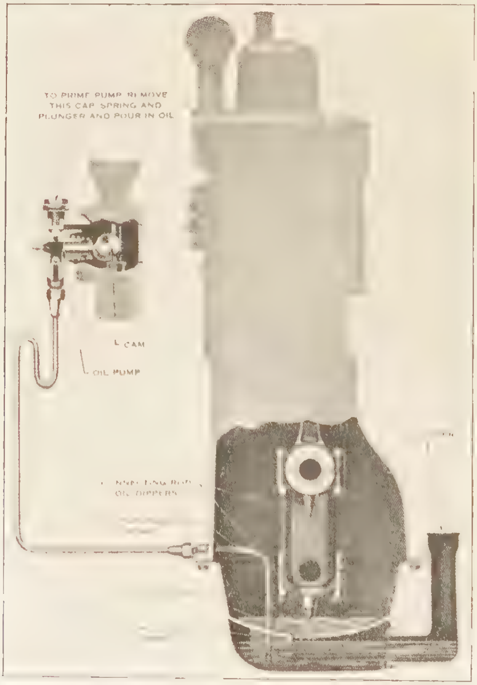

TO PRIME PUMP REMOVE THIS CAP SPRING AND PLUNGER AND POUR IN OIL
CAM
OIL PUMP
CONNECTING ROD OIL DIPPERS

Figure 57.—Splash lubricating system

704. In the splash-pressure system the main bearings are supplied with oil under pressure and the remainder of the engine is lubricated by spray and mist. Splash troughs and scuppers are essential with this system.

705. On the Model T Ford and some other models no longer made, oil is circulated by the flywheel. The lower part of the flywheel dips into the oil reservoir, and a certain amount of oil clings to its surface as it rotates and is thrown up into a pipe, whence it flows to the front of the engine, and thence into the various splash troughs. This simple system works satisfactorily as long as there is a supply of oil and the pipe does not become clogged. But as the system does not include an oil-pressure gage to notify the driver, clogging of the pipe may be followed by serious results. The pipe is not likely to clog if the engine oil is changed frequently. Because of the absence of an oil-pressure gage, overheating of the engine or loss of power in these cars should be viewed with the greatest concern, because if the cause is lack of oil, further running of the engine will result in burned-out bearings, scored cylinders, etc. To determine whether the pipe is clogged or not, examine the cooling system, see paragraph 1559. If no defects are found and the spark is properly timed, the lubricating system is probably at fault, and you should proceed as described in paragraph 744.

706. In addition to changing the oil every 500 to 1,000 miles, it is advisable at this time to fill the engine with two quarts of kerosene, after draining out the old oil, running the engine at a moderate speed for about 20 seconds. Drain the kerosene, and put a quart of oil into the crankcase. Run the engine 20 seconds and remove. In this way most of the kerosene lying in the splash troughs is removed. Old strained oil is good enough for this purpose. Finally, fill oil reservoir full of new oil. No splash or splash-pressure system should be flushed with kerosene unless subsequently treated with old oil as described.

PUMPS

707. Three types of pumps are used: The rotating vane pump; the gear pump (Figure 58), and the plunger pump (Figure 57). In the gear pump the rotation of the gears which fit closely into the housing carries oil around in the spaces between the teeth, thus delivering it under pressure at the discharge side. The plunger pump works like a syringe, the plunger usually being operated by a cam or eccentric on the camshaft, the plunger being held in continuous contact with the cam by a spring. Automatic suction and discharge valves are required with the plunger pump, but no valves are needed with the vane or gear pump.

708. If the oil pump is high up on the crankcase it may be necessary to prime it after draining the oil from the engine, whereas if the pump is in the oil reservoir, it is flooded with oil as soon as the reservoir is filled. Pumps that require priming usually have a plug or cock handy (Figure [illegible]).

709. The oil system is invariably equipped with a strainer, which is generally on the suction side of the pump. The strainer should be removed every few thousand miles and washed in kerosene. In some cars it is necessary to remove the oil pan to reach the strainer, although generally the strainer is easily accessible. Similarly, the oil pump is accessible, although occasionally the oil pan must be removed to reach it.

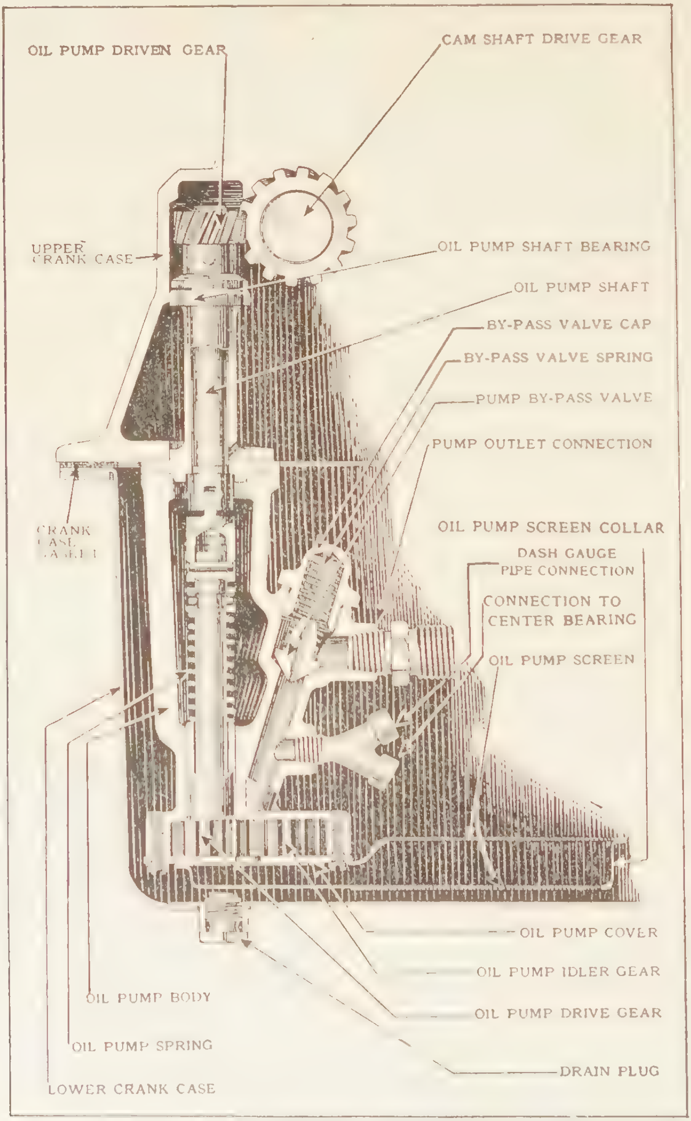

OIL PUMP DRIVEN GEAR
CAM SHAFT DRIVE GEAR
UPPER CRANK CASE
OIL PUMP SHAFT BEARING
OIL PUMP SHAFT
BY-PASS VALVE CAP
BY-PASS VALVE SPRING
PUMP BY-PASS VALVE
PUMP OUTLET CONNECTION
CRANK CASE GASKET
OIL PUMP SCREEN COLLAR
DASH GAUGE PIPE CONNECTION
CONNECTION TO CENTER BEARING
OIL PUMP SCREEN
OIL PUMP COVER
OIL PUMP IDLER GEAR
OIL PUMP DRIVE GEAR
OIL PUMP BODY
OIL PUMP SPRING
DRAIN PLUG
LOWER CRANK CASE

Figure 58.—Gear oil pump on Buick car

710. Nearly all lubricating systems with positive pump oil circulation include a pressure gage on the instrument board which indicates whether the pump is working. A pressure reading is also a fair guarantee that oil is being delivered to all parts of the lubricating system; but it is not an absolute guarantee. An oil-level gage or measuring rod is found on the side of the crankcase, but remember that these devices are accurate only when the car stands on level ground, neither sloping fore and aft nor sideways. On a few cars the oil level is determined by cocks on the side of the crankcase. When oil flows out of the upper cock the system is full, and oil should be added whenever oil fails to flow out of this cock. Dirt occasionally clogs these passages, therefore, if oil fails to flow, the passage should be cleaned with a wire; if necessary, remove the cock.

711. On most cars oil is drained from the engine by removing a plug in the bottom of the crankcase. After the oil has been drained the plug should be put back in place with the greatest care, as loss of this plug while driving might ruin the engine through continued operation without oil.

OIL CONSUMPTION HIGH

712. Symptom—Oil consumption too high.

713. Cause—(1) Leakage past pistons. (2) Oil too light or of poor quality. (3) Leakage. (4) Pump pressure too high. (5) Speed.

714. Cure—1. It is easy to determine definitely that leakage past the pistons is the cause of high oil consumption. If causes 2, 3, 4, 5 are eliminated, the trouble is cause 1, and this view is confirmed if the engine has run 10,000 to 20,000 miles without new piston rings, or 30,000 to 40,000 miles without refinishing of cylinders and fitting of new pistons and rings. See paragraph 670. A repairman's opinion should be taken.

715. If it is apparent that an excessive amount of blue smoke issues from the crankcase when the engine is running with throttle one quarter open, excessive leakage of oil past the pistons is indicated. Blue smoke issuing from the exhaust indicates that an excessive amount of oil is reaching the combustion chambers due to leakage past pistons, or thin or poor quality oil, or defect in lubricating system. See Blue Smoke, paragraph 762.

716. Cure—2. Use oil obtained from a reputable manufacturer, and buy it only in sealed cans. Use the thickness or body of oil recommended by the car or lubricant manufacturer, and if this information is not available, use medium oil.

717. Cure–3. Crawl under car and examine crankcase for oil leaks. Have a repairman fix any serious leaks noted, or, if you wish to do this work yourself, put in a new crankcase gasket if leakage occurs between upper and lower halves of crankcase. Leakage from front or rear main

engine bearings indicates need for new oil washers, if these are fitted. The lower half of the crankcase must be removed to do either of these jobs.

718. Cure—4. On cars equipped with pressure or splash-pressure lubricating systems a pump pressure too high will cause an excessive amount of spray to issue from the bearings, resulting in excessive oil being consumed in the combustion chambers. The remedy is to reduce the pressure by means of the adjustment provided for this purpose. It is not likely, however, that the pump requires adjusting unless you have specific reasons for suspecting the adjustment. It is best to have an experienced repairman check this point. It is useless to attempt to quote normal oil pressure figures, or to attempt to describe the pump adjustment as these things vary so on different cars.

719. On cars equipped with pressure or splash-pressure lubrication, excessive spray from the bearings is more likely to be due to worn bearings, abnormal oil consumption resulting. If the oil-pressure gage registers less than normal this possibility must not be overlooked. See paragraph 732.

720. On cars equipped with splash lubrication, over-oiling of the engine, accompanied by excessive oil consumption, will result from connecting-rod scuppers which are too long, or from the oil level in the troughs being too high. Both of these troubles are uncommon but are worth keeping in mind. If the cause of over-oiling is obscure it is advisable to obtain the correct scupper length, and oil-trough level from the car manufacturer, and supply your repairman with this information, while he is looking for the cause of the trouble.

721. Cure—5. As a general rule the oil consumption increases rapidly with the speed. If an average speed of 60 miles an hour is maintained the oil consumption usually will be much more than if the average is 30 miles per hour. This fact must be remembered, otherwise the engine may be run dry of oil when fast driving is continuous.

OIL CONSUMPTION LOW

722. Symptom—Oil consumption too low.

723. Causes—(1) Dilution of oil by fuel. (2) Water in oil.

724. Cure—1. Change oil every 500 miles in winter and every 1,000 miles in summer. As a rule, abnormally low oil consumption is due to excessive leakage of liquid fuel past the pistons, the amount more or less compensating for the oil consumed. When the oil is greatly diluted a marked reduction of power, especially when the engine is warm, will be noted, and scored cylinders, pistons, and bearings are likely to result. Excessive dilution may be caused by failure to change engine oil frequently, to a poor grade of gasoline, running with the choke out, insufficient heating of the mixture, too rich a mixture, too cold an engine (in very cold weather), and leaky pistons.

Insufficient heating of the mixture on modern engines is likely to occur only if a pipe in the heating system has become disconnected or a valve which should be open is closed. These points may be checked by inspection of the apparatus. The effect of a cold engine may be mitigated by a radiator shutter or a thermostat. A defective vacuum tank may cause excessive dilution by allowing liquid fuel to be drawn into intake manifold by way of the suction pipe running to the vacuum tank.

725. Cure—2. As a rule, water in the oil is due to the leakage of steam past the pistons, steam being one of the products of combustion. The condensation of this steam and its subsequent mixing with the oil is negligible in summer but may prove serious in winter, particularly if the engine is started and stopped so frequently that it rarely warms up to normal temperature. The period that the engine is cold may be reduced by the installation of a radiator shutter or a water thermostat, assuming that one of these devices is not already fitted. Otherwise, the remedy is to change the oil more frequently, oftener than every 500 miles if necessary. Sometimes water in the oil is due to leakage, either through the cylinder head gasket or through a small hole or crack in the cylinder walls or the cylinder head. Sometimes the crack will only be evident when the engine is warm.

OIL PRESSURE HIGH

726. Symptom—Pressure too high.

727. Causes—(1) Oil too heavy or cold. (2) Gage defective. (3) Pressure regulator requires adjusting. (4) Piping clogged.

728. Cure—1. Excessive pressure will be noted when the engine is cold or the oil is too heavy. Oil pressure at any given speed will be much higher with fresh oil than old oil. If pressure is excessive in cold weather, use a lighter oil. Lighter oil in winter is *imperative* in an engine with aluminum pistons and pressure lubrication—if rapid piston wear is to be avoided.

729. Cure—2. A defective pressure gage is uncommon. If the hand comes approximately to zero when the engine is stopped the gage is probably correct. A defective gage should be replaced.

730. Cure—3. If it is assumed that the pressure regulator was correctly adjusted in the beginning, it is not likely to require readjusting unless it has been tampered with. If pressure can not be adjusted satisfactorily, examine regulator for defects.

731. Cure—4. Excessive pressure may be caused by clogging of the oil delivery piping beyond the gage, that is, between gage and engine. Sometimes this piping is accessible and may readily be removed for examination and cleaning; otherwise, the pipe should be blown out with compressed air, using the tire pump if necessary. Disconnect the pipe at or near the

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gage, and attach rubber air hose to it. If this does not cure the trouble, it is best to have a competent repairman work on the car.

OIL PRESSURE LOW

732. Symptoms—Pressure too low.

733. Causes—(1) Oil supply low. (2) Oil too thin. (3) Strainer dirty. (4) Piping clogged. (5) Leakage in oil piping. (6) Pressure regulator requires adjusting. (7) Gage defective.

734. Cure—1. Examine oil level. Oil reservoir should never be less than half full. Some engines will register low pressure when going down hill even when reservoir is partly full.

735. Cure—2. Change oil, if it has not been changed within 500 to 1,000 miles.

736. Cure—3. Remove oil pump strainer and clean it in kerosene. If the strainer has not been cleaned in 5,000 miles the trouble is likely to be here. In winter, low oil pressure may be due to clogging of suction screen with "liver deposit" which is a semi-solid emulsion of water and oil, the water being a product of combustion which leaks past the pistons. The freezing of water may also result in no oil pressure. In the former case trouble is cured by cleaning, the latter by thawing in a warm garage. Further trouble may be prevented by changing the oil more frequently.

737. Cure—4. Low pressure will be caused by clogging of suction pipe to pump, or by clogging of discharge pipe between pump and gage. Have oil piping blown out with compressed air. If the oil pump is accessible, disconnect pipe on discharge side (side to which gage is connected) and run engine for a few revolutions. If heavy stream is discharged by pump, the suction line is all right, and pipe running to oil gage is clogged. (Stream will be intermittent with plunger pump.) Disconnect pipe at gage and blow out with compressed air, using mouth in an emergency. If dirt is thus dislodged, reconnect pipes and note if gage registers correctly. If no dirt in gage pipe is noted the trouble must be on the suction side of the pump, and this is confirmed if pump discharge is weak. Disconnect suction line at pump, and blow out with compressed air. It must also be kept in mind that pump discharge may be weak due to worn parts in gear and vane pumps, and to worn parts including weak or broken spring or leaky valves in the plunger pump.

738. Cure—5. Leakage anywhere in the oil piping is likely to result in lowered pressure. On all external piping look for loose points, which should be tightened, a split pipe is also a possibility, the remedy is replacement. It is difficult to discover an internal leak except by taking the engine apart. It should be noted that on engines equipped with pressure or splash-pressure lubrication, the oil pressure will drop as bearing wear proceeds, although the effect is likely to be more noticeable on the pressure system. This trouble

is not serious and may be ignored as long as the bearings are not sufficiently worn to knock.

739. Cure—6. Adjustment unlikely, if correct in the first place. There is also the possibility of a broken spring or a worn valve in the regulator. If the cause of low pressure is not found elsewhere, remove the regulator and examine it for these defects.

740. Cure—7. If the gage hand comes to zero when the engine is stopped it is correct; otherwise replace it.

NO OIL PRESSURE

741. Symptom—No pressure.

742. Causes—(1) Oil too low. (2) Piping clogged. (3) Oil piping disconnected. (4) Pump strainer stopped. (5) Pump broken. (6) Ice. (7) Pressure regulator broken. (8) Gage defective. (9) Pump requires priming.

743. Cure—1. Lack of oil in the reservoir is the most frequent cause of no pressure. Examine oil-level gage and be sure it is not sticking. Tap the gage vigorously or add oil and note if the gage moves. A sticking oil-level gage should be removed and examined for mechanical defects.

744. Running a car with no pressure on the oil gage is sure to result in a ruined engine unless the defect is within the gage or in the pipe running to the gage. The safest plan is not to run the engine until the trouble is found and cured. The next best suggestion is to fill the engine with oil until it smokes slightly. Several gallons may be required, and additional oil should be put in every few miles to keep it smoking. If oil is unavailable, the third suggestion is to drive slowly, and stop the engine as soon as loss of power or a tendency to knock is noted. From this point the car should be towed unless it is subsequently filled with oil as described.

745. Cure—2. Disconnect oil pipe on discharge side of pump (same side as oil-pressure gage). Run engine a few seconds and note if discharge is heavy or light. If heavy, disconnect pipe at gage and blow it out with compressed air. If light, or absent, disconnect suction pipe at pump and blow it out. If this does not cure trouble, see cure 5.

746. Cure—3. Examine all external oil piping for loose or broken connections, split pipes, and the like.

747. Cure—4. If trouble is still undetermined, remove pump strainer and clean if required. Cure—5. Remove pump, take it apart and examine it closely for obvious mechanical defects.

748. Cure—6. If there is water in the oil, freezing anywhere in the system may prevent the circulation of oil. The trouble should disappear when the car is placed in a warm garage, or if the pump is not frozen solid, running the engine for a few revolutions may be sufficient to melt the ice. The oil may also be congealed, in which case the trouble will disappear when the

engine is warmed. A recurrence of this difficulty may be prevented by using an oil with a lower cold test. If the pump is frozen solid it may be impossible to crank the engine, or if it is cranked, the pump or its drive may be broken. Sometimes the pump may be thawed by hot wet cloths, but otherwise a warm garage will be required. Troubles due to water in the oil may be avoided by changing the oil every 500 miles.

749. Cures—7 and 8. Examine pressure regulator and gage. Cure—9. Prime pump. See paragraph 708.

GAGE-HAND FLUTTERS

750. Symptom—Pressure-gage hand flutters.

751. Causes—(1) Oil supply low. (2) Leakage in piping. (3) Pipe between gage and pump intermittently clogged. (4) Suction line to pump intermittently clogged. (5) Pump strainer dirty. (6) Intermittent defect in pump.

752. Cure—(1) Examine oil-level gage, adding oil if required. (2) Examine all external piping for leaks (air in or oil out) and tighten *all* connections. (3) Blow out pipe between oil gage and pump with compressed air. (4) Blow out suction line to pump with compressed air. (5) Remove pump strainer and clean it. (6) Remove pump, take it apart, and repair any obvious defects such as a broken spring.

OIL-LEVEL GAGE STICKS

753. Symptom—Oil-level gage sticks.

754. Cause—Mechanical defect.

755. Cure—Remove gage mechanism and examine it carefully for obvious mechanical defects, and repair as required. The mechanism is simple, therefore this general advice should be sufficient.

OIL-LEVEL GAGE LOW

756. Symptom—Oil-level gage reads too low.

757. Cause—Float oil soaked.

758. Cure—Remove float. If it is cork, wash it in gasoline, dry it thoroughly, put in a warm oven for a few hours, and shellac carefully, or preferably install a new cork float. If float is of metal, shake it to determine if there is any oil inside. If so, treat as described in paragraph 946, for gasoline floats.

BLUE SMOKE IN EXHAUST

759. Symptom—Blue smoke in exhaust.

760. Cause—If an excessive amount of oil makes its way to the combus-

tion chambers, blue smoke will appear at the exhaust due to the part burning of this oil. Oil consumption, however, may be high without producing a blue exhaust. Blue smoke indicates high oil consumption, but the reverse is not always true. Blue smoke may be due to an excess of oil being thrown on the cylinder walls, to the use of too light an oil, or to undue leakage of oil past the pistons.

BLUE SMOKE FROM BREATHER

761. Cure—See oil consumption high, paragraph 712.

762. Symptom—Blue smoke from breather.

763. Cause—A noticeable amount of blue smoke from the breather at ordinary engine speeds is likely to indicate that the pistons, rings, or cylinders are sufficiently worn to allow an excess of oil to reach the combustion chambers, where it is partly burned and then blown back past the pistons into the crankcase. If excessive wear is limited to just one cylinder, puffs of blue smoke are likely to be seen once every other revolution of the engine.

764. Cure—See paragraph 670.

FOUL SPARK-PLUG

765. Symptom—Foul spark-plug.

766. Cause—A spark-plug may be fouled (dirtied) with oil or carbon. If the plug is found to be covered with oil the most likely explanation is that this cylinder has been missing for some reason or other, and thus has collected considerable oil spray. This spray would have burned off as fast as collected if the cylinder had not been missing.

767. If an excessive amount of oil is delivered to the combustion chamber due to any of the causes previously outlined, more oil spray may collect on it than can be burned away, with the result that the surface of the porcelain becomes covered with a mixture of half-burned oil and carbon, and perhaps also the spark-plug points have collected a drop of oil which is bridging the gap. Either condition is sufficient to prevent the firing of the plug. Even if the engine operates without plug-fouling under ordinary circumstances, plugs may foul when coasting down a long hill with ignition shut off and the car running the engine.

768. If the spark-plug in a single cylinder fouls, it is rather conclusive evidence that new rings are required in this cylinder, and this is sometimes true even though the car has only been run a few hundred miles. Running a few miles with insufficient lubrication may ruin the piston rings in one or more cylinders.

EFFECT OF TEMPERATURE ON OIL

769. On many engines the same oil may be used the year round, but the best course is to take the advice of the leading oil manufacturers regarding your own car. However, if this information is lacking, oil used in hot weather should be just heavy enough so that the consumption is within reason. If it is too light it may become too thin and therefore fail to lubricate properly; if it is too heavy, an excessive carbon deposit will occur and engine friction will also be increased. If the climate is intensely hot or if the engine runs hotter than it should, a heavier oil than recommended may be advisable.

770. In cold weather the oil should be sufficiently fluid to lubricate the engine under all circumstances. If an oil becomes solid at 20° below zero, it is obviously possible to burn out the engine bearings if this temperature is reached even though the reservoir is full of oil. In winter the oil purchased should have a cold test sufficiently low to stand the lowest temperature experienced. In buying an oil, therefore, be sure that it will not congeal at the minimum temperature; on the other hand, a reputable oil company is not likely to sell an oil unsuitable for the climate.

Chapter VIII

THE ENGINE COOLING SYSTEM

801. The main features of the water-cooling system have already been described and therefore need not be repeated here—see paragraph 40. Additional details, however, must be given to enable the reader to care for the cooling system properly.

802. Inasmuch as water expands when heated, if the cooling system is filled with cold water, some water must be discharged from it when the system becomes warm. The usual method is to have a vent pipe opening into the top of the radiator; water flows out of this pipe on to the ground as expansion occurs. Water will also flow out of this pipe if the radiator is filled too full. Therefore the reader should not regard discharge of water through the vent pipe as a leak, because it is a normal action. Some water is also lost through the vent pipe by evaporation, although on a few cars evaporation is prevented by a condenser attached to the vent pipe.

803. The radiator is connected to the engine by rubber hose; cool water flows from the bottom of the radiator to the engine, and hot water from the engine flows to the top of the radiator. The hose is fastened by various types of clamps, and small leaks are likely to develop at the hose connections, but these are cured by tightening the clamps.

804. After the hose has been in use a year or two, the interior may rot sufficiently so that pieces of rubber are detached from it and these may swing across the water passages and completely stop or greatly reduce the circulation, thus causing overheating. To avoid this difficulty as well as the danger of rotted hose leaking, it is advisable to install new hose when it begins to disintegrate.

PUMPS

805. Most water pumps (Figure 59), consist of an impeller wheel with several vanes on it, rotating in the pump housing. Water enters at the center and is thrown out by centrifugal force. If pieces of rubber are delivered to the pump, the vanes may break or the pin which holds the vane to its shaft may break, and this pin may also work loose due to vibration alone. These defects are easily discovered by disassembling the pump. The pump housing is made in two pieces, with a paper gasket shellacked on both sides between them. If the pump is taken apart a new gasket should be provided. Any flanged water connections in the system are also provided with paper gaskets

which should be shellacked on both sides. A gasket may be readily made by taking a sheet of thick wrapping paper and laying it on the surface it is to cover; the gasket is cut out of the paper by pounding the edges of the surface with a hammer.

806. The pump shaft is supplied with one or two packing-gland nuts, only one being necessary if the shaft does not go clear through the pump.

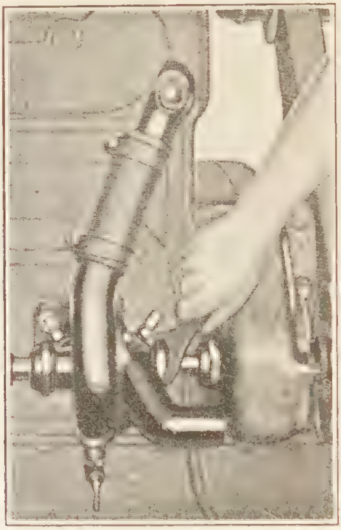


Figure 59.—Water pump on Dodge car

When leakage occurs at these glands, the nuts must be turned just enough to stop the leakage. If the nuts are turned up too tight, the shaft may bind and some part of the pump driving mechanism may break. The pump bearings should be lubricated with grease every 500 miles. If turning up the gland nuts does not completely stop the leakage, try a heavier grease. If leakage continues, unscrew the gland nuts all the way, remove the old packing (it looks like string wound around and around the shaft) and put in new packing, bought at any accessory store. If the pump bearings are badly worn, the new packing may not prevent leakage entirely, in which case new bushings must be installed. This work should be done by an experienced repairman. Need for new bushings is indicated by noticeable play in the pump shaft when it is shaken with the hand.

LEAKS

807. Leakage may also occur in the radiator or in the engine. Occasionally, blow-holes exist in the cylinder casting, allowing water to leak into

the combustion chambers (see paragraph 723) or blow-holes in the water jackets will allow leakage of water down the sides of the exterior. Have an experienced repairman repair these leaks. If the engine has been allowed to freeze, the water jackets may develop cracks without any other damage being done, leakage resulting. If the cracks are not too large they may be stopped by using a good radiator compound; otherwise, welding will be required.

808. Leaks around the cylinder-head gasket may often be stopped by tightening the cylinder-head nuts; otherwise, a new gasket will be required.

809. Continued vibration is likely to cause leaks to appear in the radiator after a time, and these should be soldered by an expert radiator repairman. A good temporary repair can, however, be effected by the use of a radiator compound.

810. Here it should be noted that it is not advisable to use cornmeal or other home-made remedies for stopping radiator leaks, as these materials clog the radiator pores and interfere with circulation. However, there are on the market a number of excellent radiator compounds which will not interfere with circulation or otherwise harm the cooling system. To be sure, it is advisable to have the liquid recommended by someone who has had actual experience with it.

811. A radiator which has been frozen is often ruined thereby, although if it has only a few small leaks, they may be repaired by soldering by a radiator man or radiator compound may be used.

812. Clean, soft water only should be used in filling the radiator. Hard water obtained from spring or well is likely to leave a deposit which will eventually clog the system.

CLEANING RADIATOR

813. The cooling system should be drained every few thousand miles to remove dirt and particles of rust. If the radiator is not drained for 15,000 or 20,000 miles the lower portion is likely to become so filled with sediment that circulation is greatly impeded if not actually stopped.

814. The radiator is drained by opening a drain cock or removing a plug in the bottom of the radiator. If there is much sediment it may be necessary to remove the cock, and even then it may be necessary to clear the hole with a small stick or wire before the water will flow. When this occurs it is time to flush the radiator, although it is a good plan to flush it anyhow every few thousand miles. To do so, detach the lower hose connection, place a garden hose in the filler opening and allow water to run through until it flows clean. Sometimes it may also be necessary to remove the cylinder head and clean mud out of the jackets.

815. If there is not too much sediment in the radiator it may be loosened by making a strong solution of washing soda in water and filling the radiator

with it, allowing the engine to run for half an hour thereafter, when the system may be drained. This method, however, will not always loosen the sediment so that it will pass out the drain cock. On the other hand, it is a good plan to use this soda treatment before flushing the radiator.

816. The radiator may be removed, when required, by unscrewing the nuts underneath it, detaching the hose connections and the brace rod which runs to the dash.

817. The fan belt should be adjusted as required. It should be tight enough to drive the fan without appreciable slippage and yet not tight enough to place a strain on the fan bearing. The method of adjustment varies with different cars, but it is always an obvious adjustment.

818. To enable the engine to warm up quickly, especially in cold weather, many cars are provided with a thermostatic valve or a radiator shutter, although both are rarely used. The thermostatic valve is usually placed on the cylinder-head casting; sometimes it is connected so that when the engine is cold the water flowing through the cylinders does not flow through the radiator; in other words, the cylinders are short-circuited. As the engine warms up the thermostat expands, thus opening a valve which allows more and more water to go through the radiator, all water flowing through the radiator when the engine is thoroughly warm. The thermostat therefore not only permits the engine to become warm in minimum time, but it maintains the engine at a constant warm temperature of about 180°, regardless of how cool the weather is. Radiator shutters throttle the amount of air passing through the radiator. The shutter may be thermostatically controlled, being closed when the engine is cold and opening automatically as the engine warms up, or it may be hand controlled by a lever on the instrument board. In the latter case a radiator thermometer should be used. The shutter is allowed to remain closed until the thermometer indicates normal engine temperature, when the shutter is adjusted to keep the engine at this temperature, the shutter being opened part way in cold weather and all the way in warm weather.

ANTI-FREEZING SOLUTIONS

819. When a car is exposed to freezing weather the radiator should be filled with an anti freezing liquid. There should be no exceptions to this rule. Nevertheless, many motorists run the risk of big repair bills during winter weather by failing to use an anti-freezing liquid. They assume that if their cars are kept in heated garages, and not allowed to stand too long in the cold, there is no danger of freezing. Unfortunately, when a man starts out with a car it is impossible for him to tell how long his car may be exposed to the weather. For example, the engine may stall several miles from a garage, and before help is obtained, the cooling system may freeze

solid. Therefore if a car must be left alone, when it is not filled with anti-freeze liquid, it is advisable to drain the radiator. Many cooling systems have been ruined by exposing them to unexpectedly frosty nights in the fall or spring. The safest plan is to put in anti-freeze liquid early and keep it in late.

820. A number of specially prepared anti-freezing compounds may be purchased at reliable stores; in addition, denatured grain or wood alcohol, glycerin or pure calcium chloride may be used. It is important to put in sufficient liquid so that the freezing temperature will be down to the low limit. If the capacity of the cooling system is unknown, it is advisable to drain the radiator, measuring the quantity of liquid obtained; it does not pay to guess. Alcohol evaporates readily and alcohol only should be added from time to time; never water. For the sake of economy and accuracy, all leaks in the cooling system should be fixed before putting in the anti-freeze liquid.

ALCOHOLS

821. The amount of alcohol to use to obtain a given freezing point depends on its strength. Assuming 188 proof denatured grain alcohol, the following proportions may be used:

Freezing point, degrees Fahrenheit	*Alcohol, quarts*	*Water, quarts*
20 above	1	5
10 above	1	4
Zero	1	3
10 below	1	2
25 below	1	1

822. Another anti-freezing liquid is Prestone, the trade name for ethylene glycol. This is a polyhydroxyl alcohol and has a wide range of uses, such as in flavoring extracts to an anti-freeze component in certain explosives. It is a colorless liquid, without odor, is non-toxic, has low volatility, is non-flammable, and is more viscous than water. Ethylene glycol boils at 387° F., whereas water boils at 212°. A 40:60 Prestone-water mixture gives a freezing temperature of about 10° below zero, and whereas wood alcohol evaporates readily and costs one third the price of ethylene glycol, the latter does not evaporate and will remain in the radiator all winter, provided that there is no leakage.

GLYCERIN

823. Specially prepared glycerin for automotive use, unlike previous glycerins, flows readily, and has the advantage that it does not evaporate

perceptibly. Therefore, once the radiator is filled, no more glycerin need be added throughout the winter, although water must be added to replace evaporation. As glycerin is expensive, the cooling system must be proof against leakage before the glycerin is put in.

Whether glycerin or alcohol is used, it is advisable to test the strength of the solution from time to time with an hydrometer made for the purpose, the cost of this instrument being about $1.

824. The amount of glycerin to use depends on its strength. The following figures are for Ivo distilled radiator glycerin made by Proctor and Gamble. As a rule, the amount of glycerin to use for a given freezing point will be found on the label on the can:

Freezing point, degrees Fahrenheit	*Glycerin, quarts*	*Water, quarts*
10 above	5	5
Zero	6⅔	3⅓
10 below	7½	2½
20 below	8¼	1¾
30 below	9	1

825. Before putting in the anti-freeze solution it is advisable to flush the radiator as described in paragraph 813. All leaks should also be fixed.

826. When alcohol or glycerin or mixtures of these are used the cooling effect is not as good as with pure water, and therefore it is important to drain the liquid and fill the radiator with fresh water before hot weather is experienced. As a matter of economy the anti-freezing liquid may be drained and saved until next year, provided that it is kept in an air-tight vessel.

Chapter IX

THE FUEL SYSTEM

901. The principal features of the fuel system have already been described in paragraph 43. If the gasoline tank is under the cowl or under the front seat, fuel usually flows by gravity to the carburetor. But if the tank is placed at the rear of the car some other means must be used to cause the fuel to flow to the carburetor. The Stewart vacuum system is used on many of these cars, although the Kingston Oil-Vac system is used to a limited extent, while the AC fuel pump and filter is a development on several recent cars (Figure 60). Cadillac and LaSalle use a vacuum pump driven from the rear of the camshaft. This automatically supplies suction to the vacuum tank when intake manifold suction is negligible, as it always is with throttle wide open.

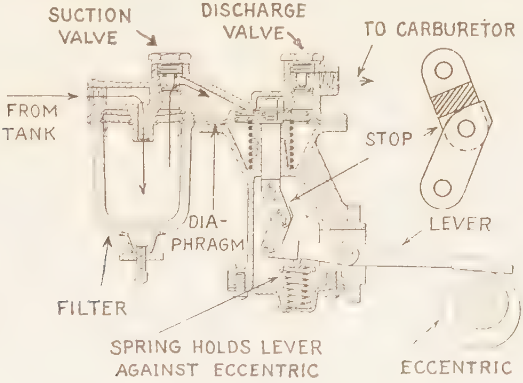


Figure 60.—The A C fuel pump and filter

902. The AC fuel pump is a diaphragm pump and has a filter combined with it. The rotation of the eccentric on the camshaft pulls the diaphragm down, drawing fuel from the rear tank past the suction valve into the diaphragm chamber. On the upstroke the diaphragm spring pushes the fuel past the discharge valve into the carburetor. When the carburetor float chamber is full of fuel and the float valve is closed, pumping ceases because the diaphragm spring does not possess sufficient strength to force the float valve off its seat. At ordinary speeds, the diaphragm moves upward only a

few thousandths of an inch from its lowest position because the engine requires only a half dozen small drops of fuel for each revolution of the camshaft. Only when the carburetor bowl is empty does the diaphragm make a few full strokes.

903. In all systems excepting the pressure system, there must be a small air hole in the filler cap on the gasoline tank, and if this hole becomes stopped up fuel will refuse to flow. On the other hand, air or exhaust pressure systems require a tight fitting filler cap without an air hole in it.

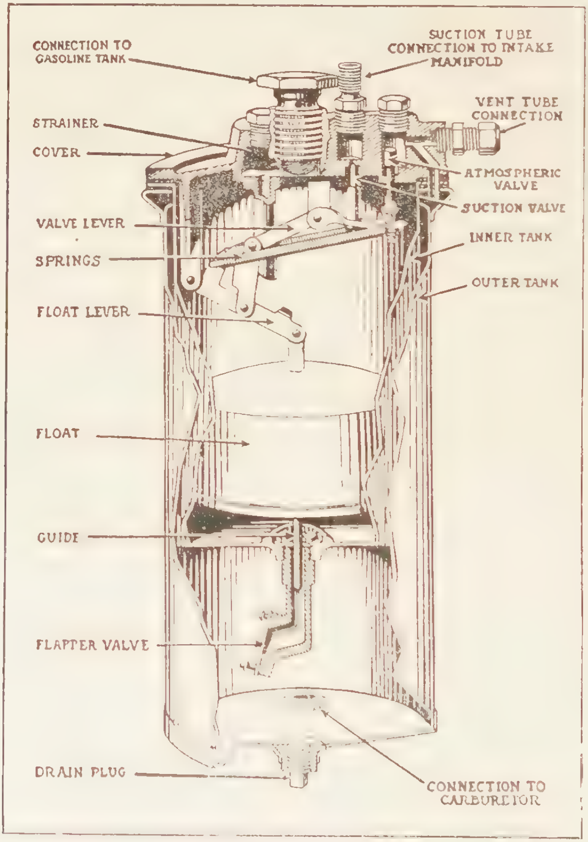

CONNECTION TO GASOLINE TANK
SUCTION TUBE CONNECTION TO INTAKE MANIFOLD
VENT TUBE CONNECTION
STRAINER
COVER
ATMOSPHERIC VALVE
SUCTION VALVE
VALVE LEVER
INNER TANK
SPRINGS
OUTER TANK
FLOAT LEVER
FLOAT
GUIDE
FLAPPER VALVE
DRAIN PLUG
CONNECTION TO CARBURETOR

Figure 61.—Stewart vacuum system of fuel feed

STEWART VACUUM SYSTEM

904. In the Stewart system the vacuum tank permits the engine suction in the intake manifold to draw gasoline from the rear tank and deliver it by gravity to the carburetor. The gasoline from the rear tank flows through a

pipe into the top of the vacuum tank, and flows to the carburetor through a pipe at the bottom. A suction pipe runs from the top of the vacuum tank to the intake manifold (Figure 61).

905. The vacuum tank consists of an upper and lower chamber separated by a metal partition. The engine suction draws gasoline into the upper chamber and when the chamber is nearly full, the float suddenly rises and closes a valve which shuts off the suction. Simultaneously, the float opens a valve allowing atmospheric air to rush in. Then the gasoline flows by gravity to the lower chamber. When the upper chamber is empty, the float suddenly drops to the bottom, closing the atmospheric valve and opening the suction valve, when the upper chamber begins to fill with gasoline again. The suction can not draw fuel back up from the lower chamber because a flapper valve allows fuel to pass down but will not allow it to pass up.

VACUUM-TANK REPAIR

906. The need for repairing the vacuum system is extremely unlikely, but if repairs are necessary, the following instructions prepared by the Buick Motor Co. may be used:

Disassembly—Disconnect suction pipe from manifold gasoline line from gasoline tank, and to carburetor. Take out screws in cover and remove cover and float. Remove inner tank. Be careful not to destroy the cork gaskets between cover and inner tank and between inner and outer tank. *Inspection*—Shake float to determine if there is any gasoline in it. Place float in warm water for a moment to determine point of leakage, as air bubbles will be seen at this point. Then drill or carefully punch small hole in float to allow gasoline to drain out. Then solder both holes using as little solder as possible. Inspect suction and atmospheric valves in cover. See that they are clean and that seats are bright all the way around. See that the seat bushings in cover are tight. Inspect springs and levers. See that springs have approximately the same tension and that all pins are in place on levers. Move float up and down the full length of its travel. Note that each valve seats and unseats properly. Inspect inner tank. See that tank and passageway through flapper valve stem are clean and that flapper valve seats evenly all around. Inspect outer tank. See that tank and openings at drain plug and gasoline line connection are clear. Inspect vent passage in cover. With float at bottom of its travel it should be possible to blow freely through the vent connection and pipe. Inspect shut off valve. See that it is free from dirt. All defective parts should be replaced. When reassembling be sure that both cork gaskets are in good condition and tighten cover screws evenly.

KINGSTON VACUUM SYSTEM

907. In the Kingston Oil-Vac system the vacuum instead of being supplied by the intake manifold is produced by a vane pump (Figure 62), which runs in oil obtained from the lubricating system. If the oil supply fails the pump will not produce sufficient suction, therefore damage to the engine due to lack of oil is impossible. The suction produced by the pump causes oil to flow through it but the suction side of the pump is also connected to the vacuum tank, thus sucking air as well as oil. The suction pipe and the pipe from the gasoline tank are connected to the top of the vacuum tank (Figure 63), while the pipe running to the carburetor is connected to the bottom of the vacuum tank. Suction produced by the oil pump is continuous, and the float has a continuous action, and not intermittent as in the Stewart Vacuum System. When fuel rises beyond a certain level in the upper chamber, the float rises and opens the valve, allowing fuel to flow into the lower chamber. When the engine is running, the amount that this valve is open increases with the gasoline consumption. The complete float

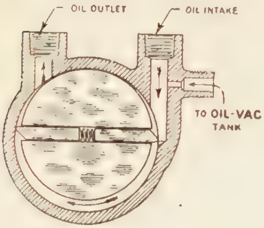

OIL OUTLET
OIL INTAKE
TO OIL-VAC TANK

Figure 62.—Section of Kingston Oil-Vac pump

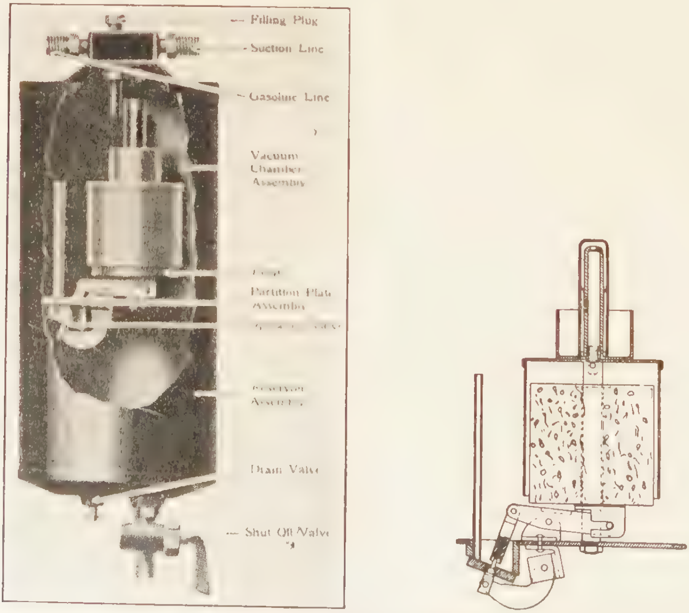

Filling Plug
Suction Line
Gasoline Line
Vacuum Chamber Assembly
Partition Plate Assembly
Drain Valve
Shut Off Valve

Figure 63. Kingston Oil Vac system of fuel feed. Right—details of valve mechanism

and valve mechanism may be removed by disconnecting the suction and upper fuel pipe, and loosening the upper clamp surrounding the tank.

908. Either type of vacuum tank should be drained occasionally to remove sediment and water, by removing the drain plug in the bottom. If the vacuum tank is emptied for any reason, it may be filled by cranking the engine with throttle closed, although if the battery is not equal to this task, the plug in the top of the tank (either Stewart or Kingston systems) should be removed and about a half pint of gasoline poured in. Be sure that the plug is screwed back tightly.

PRESSURE SYSTEM

909. On some of the older Cadillacs air pressure is automatically maintained on the gasoline tank by a pump driven from the camshaft. There is also a hand pump on the instrument board, which must be operated before starting if the car has been standing long enough to permit the air pressure in the tank to escape.

910. Any gasoline tank should be drained every few thousand miles to remove the sediment that has accumulated. As a rule there is a drain plug in the bottom of the tank, but if not the gasoline pipe should be disconnected at the tank. The fuel should be strained or allowed to settle before putting it back into the tank.

911. Some gasoline tanks are provided with an emergency supply valve, so that after the main supply has become exhausted the valve may be turned and the emergency supply used. An inspection of the tank should determine whether such a valve is fitted. If there is much sediment in the tank the mechanism may become so clogged with dirt that no fuel can be obtained when the emergency supply is turned on. Therefore, with such a valve, occasional drainage of the tank is particularly important.

912. There is more or less dirt in all gasoline, as well as dust and moisture in the air in the tank, and any car is likely to miss or to stall because of dirt. One remedy is to open all drain cocks or plugs in the system every few thousand miles, in addition, it is advisable to install a gasoline strainer, but the strainer is of little use unless it also is drained say, once a month. Unexpected stalling of the engine will be largely limited to ignition troubles if a gasoline strainer is attached. Drain cocks or plugs are likely to be found on the carburetor, strainer, vacuum tank, gasoline tank, and perhaps at points along the gasoline piping.

CARBURETOR ADJUSTMENT

913. Any man should be able to obtain a good carburetor adjustment. On the other hand, a carburetor expert is not likely to obtain the best adjust-

ment on the first trial. Perseverance is generally more important than skill.

914. Most carburetors have two main adjustments, high speed and low speed, although some carburetors have only a low-speed adjustment.

915. Before attempting to adjust a carburetor it is advisable to have all other parts of the engine in good operating condition, and the engine should be thoroughly warm, although not hotter than under average driving conditions. Unless otherwise stated, the spark lever should be placed in normal driving position while adjustments are being made.

RICH AND LEAN MIXTURES

916. In adjusting a carburetor it is important to know the difference between a rich and a lean mixture. A rich mixture will be accompanied by black smoke at the exhaust, and a lean mixture by backfiring in the carburetor. A mixture rich enough to produce black smoke is rather unusual, and some carburetors can not be adjusted to produce this extreme condition. If the mixture is lean, backfiring may occur at ordinary driving speeds, or the engine may refuse to run at all. Sometimes backfires will be noted only when the throttle is opened quickly, and if the mixture is only a trifle lean, backfiring will take place only at high speed.

917. A mixture may be too rich or too lean for greatest power and yet not produce the extreme symptoms of black smoke or backfiring. Lack of acceleration, hill-climbing ability, or speed shows you that the mixture is either too rich or too lean, but which is it?

918. The mixture is *too rich* if the car accelerates more slowly than usual but responds to the throttle the instant the accelerator pedal is depressed.

919. The mixture is too lean if the car accelerates more slowly than usual, failing to respond immediately to the opening of the throttle, a wait of a half second or so occurring before any pickup is noted.

920. Generally speaking, the best hill-climbing mixture is one that is just a trifle lean; one that gives slightly less than maximum acceleration.

TESTING THE ADJUSTMENT

921. Only an approximate setting may be obtained by adjusting the carburetor without a road test, but in this case the adjustment should be for maximum idle engine acceleration.

922. If the carburetor is so badly out of adjustment that the engine will not run, open the throttle about one-fifth, close the low-speed adjustment all the way, then open it one-half turn. If the engine fails to start open it a full turn. Manipulate the carburetor until the engine is running.

923. After the engine is thoroughly warm, close the throttle until the engine idles slowly. Then turn the low-speed adjustment slowly one way

and the other until maximum engine speed is obtained (with this throttle position).

924. Then adjust the throttle stop screw until the engine runs at its minimum speed without any tendency to stall. The throttle stop screw is a screw which limits the closing of the throttle. It will usually be found on the arm which is attached to the throttle shaft. It is provided with a lock-nut or a lock screw which must be loosened before making the adjustment and tightened again after the stop is adjusted.

925. The low-speed adjustment only affects the engine when idling or when the car is running slowly with the throttle nearly closed. The high-speed adjustment comes into action when the throttle is opened, and therefore almost entirely controls the fuel economy and power of the car when on the road.

926. Open the throttle until the engine is running at a speed approximately corresponding to 25 miles per hour on high gear and reduce the high-speed adjustment until the engine backfires, or if this is not possible close the throttle and reduce the adjustment to a point where the engine backfires when the throttle is opened suddenly. If the engine refuses to backfire, take the car out on the road, as it may backfire under load but not when idling. If it still refuses to backfire, gradually increase the adjustment until best acceleration on high gear is obtained, and if a hill is available try the speed of the car on this hill several times, gradually reducing the richness of the mixture until best hill-climbing ability is obtained. For extra fuel economy the adjustment may be reduced still further at the expense of power.

927. If the engine backfires when idling, increase the adjustment just enough to stop backfiring. Then take the car out on the road and accelerate rapidly on all gears. If backfiring occurs, increase the adjustment just enough to stop it.

928. This adjustment may be correct and then again may be only approximate and because of the latter consideration it is advisable to vary it slightly, both richer and leaner. If the car is to be used entirely in level country, it is advisable to adjust for best acceleration unless maximum economy is desired, in which case adjust only until backfiring disappears. If there are hills to be climbed try the car on a good high-gear hill, varying the adjustment slightly until maximum hill-climbing speed is obtained. To sum up, best hill-climbing ability requires a mixture that is rich enough not to backfire and yet a little leaner than required for maximum acceleration, although there are some exceptions.

929. If changing the high-speed adjustment affects the low-speed adjustment, a new low-speed adjustment must be made after the high-speed adjustment is obtained. Best adjustment on a warm day will be found too lean on a cold day, and best adjustment on a cold day will be too rich on a warm day. A richer mixture must be used in winter than in summer, and it

advisable to use a richer mixture during fall and spring, because of the occasional cold days.

930. A cold engine warms much more quickly and ceases backfiring sooner when the mixture is rich; hence, the advisability of a richer mixture in a cold climate except in summer.

931. A leaner mixture is required in high altitudes and in tropical countries.

932. Dirt or water in the fuel system may produce the same symptoms as a weak mixture, with backfiring, loss of power, missing, or perhaps occasional stalling of the engine. Even a drop of water passing through the carburetor may cause the engine to miss two or three explosions, and a spoonful of water may cause stalling. Dirt anywhere in the fuel system may interfere with the flow of gasoline and thus produce the symptoms of a weak mixture.

933. An air valve that sticks open may produce lean mixture symptoms.

934. Failure of the exhaust heating system to supply heat to the mixture will also produce a weak mixture because of imperfect vaporization of fuel. The heating system may fail due to disconnection of some of the piping or to valves which should be opened or closed.

935. The carburetor may be flooded when desired by holding the float needle valve away from its seat, until fuel drips out of the carburetor.

936. It was stated in paragraph 44 that as the throttle is opened the engine suction draws gasoline into the mixing chamber more rapidly than air, and that some means must be used to compensate this situation. The auxiliary air valve has already been mentioned, but in a great many carburetors this valve has been dispensed with, various arrangements of jets (holes through which the fuel issues into the mixing chamber) being used so that the gasoline does not come out any faster than the air. Special jets are also frequently provided for easy starting.

TYPES OF CARBURETORS

937. No attempt will be made to describe the operation of the various types of carburetors in detail, because little would be gained thereby, and the following illustrations of carburetors (Figures 64 to 73), are offered mainly to give the reader an idea as to where the various adjustments are to be found, and how they are to be used. A number of these carburetors have no high-speed adjustment, inasmuch as this adjustment is obtained by using the correct size of jet opening or openings. It is only practicable, therefore, for the reader to adjust the idling screw. It is almost certain that the jet size is correct, but if the action of the carburetor indicates that the mixture is too rich or too lean, the car should be taken to a service station.

938. While making these adjustments, note that right is clockwise and left is counter clockwise.

939. Figures 64 to 73 inclusive show various types of carburetors and their parts, therefore no description is necessary.

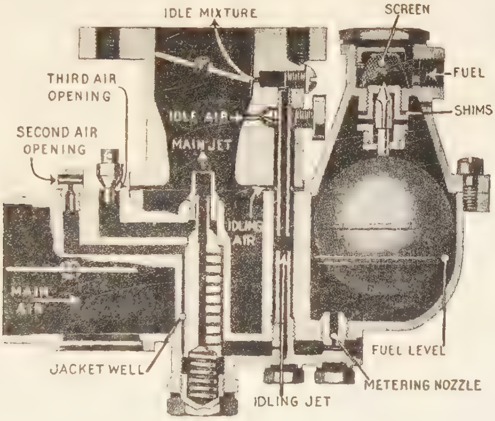

IDLE MIXTURE
SCREEN
THIRD AIR OPENING
FUEL
SHIMS
IDLE AIR
SECOND AIR OPENING
MAIN JET
IDLING AIR
MAIN AIR
FUEL LEVEL
JACKET WELL
METERING NOZZLE
IDLING JET

Figure 64.—Ball & Ball carburetor

940. Various arrangements are used for easy starting. In many cars the choke rod operates a butterfly damper in the carburetor intake passage, thus causing the engine to suck more than the usual amount of gasoline out of the carburetor. In other cars, a specially rich mixture is provided by the carburetor when the throttle is nearly closed. Most choke mechanisms should only be used while warming the engine.

941. In some machines the carburetor is heated by a hot spot which is integral with a combined intake and exhaust manifold, in which case the heating mechanism may not be apparent to the eye. In other machines the air is heated by a separate exhaust stove or the carburetor is provided with a jacket through which exhaust gases or water from the radiator circulates. In general, it is intended that this heat be employed summer and winter without any variation, but sometimes a valve is provided in the piping which permits the carburetor to draw in cold air in summer, in others the degree of heat obtained may be varied by an adjustment on the instrument board.

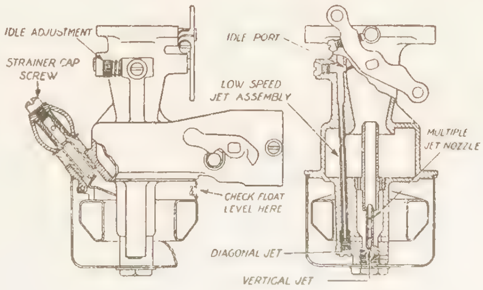

IDLE ADJUSTMENT
STRAINER CAP SCREW
IDLE PORT
LOW SPEED JET ASSEMBLY
MULTIPLE JET NOZZLE
CHECK FLOAT LEVEL HERE
DIAGONAL JET
VERTICAL JET

Figure 65.—Carter carburetor

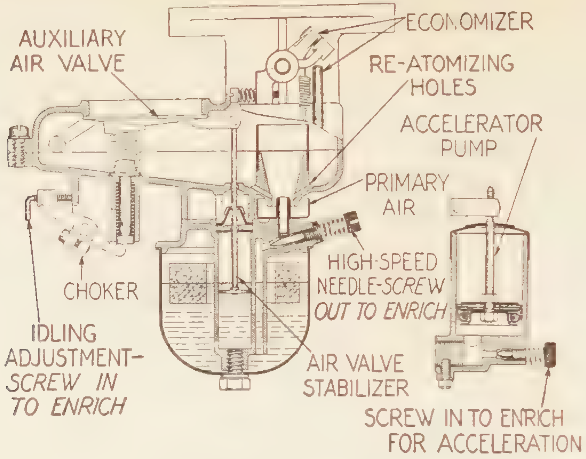

ECONOMIZER
AUXILIARY AIR VALVE
RE-ATOMIZING HOLES
ACCELERATOR PUMP
PRIMARY AIR
HIGH-SPEED NEEDLE-SCREW OUT TO ENRICH
CHOKER
IDLING ADJUSTMENT-SCREW IN TO ENRICH
AIR VALVE STABILIZER
SCREW IN TO ENRICH FOR ACCELERATION

Figure 66.—Johnson carburetor

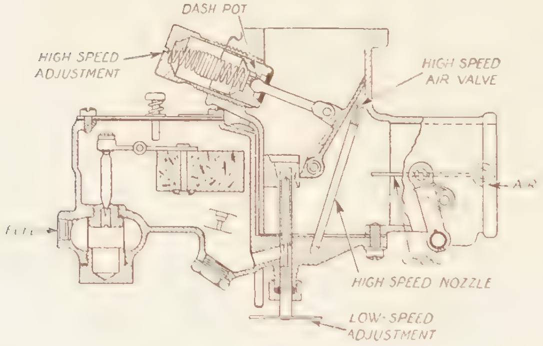

DASH POT
HIGH SPEED ADJUSTMENT
HIGH SPEED AIR VALVE
Fuel
AIR
HIGH SPEED NOZZLE
LOW-SPEED ADJUSTMENT

Figure 67.—Marvel carburetor

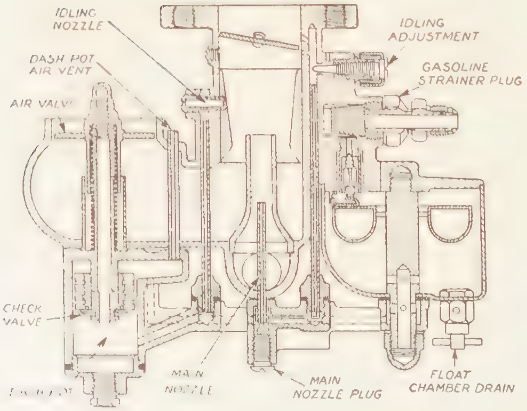

IDLING NOZZLE
IDLING ADJUSTMENT
DASH POT AIR VENT
GASOLINE STRAINER PLUG
AIR VALVE
CHECK VALVE
EXHAUST
MAIN NOZZLE
MAIN NOZZLE PLUG
FLOAT CHAMBER DRAIN

Figure 68.—Rayfield carburetor

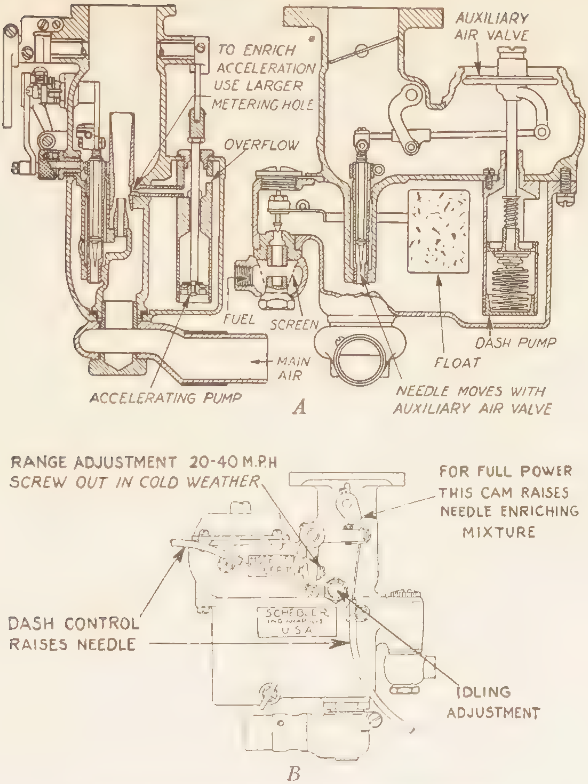

TO ENRICH
ACCELERATION
USE LARGER
METERING HOLE
OVERFLOW
AUXILIARY
AIR VALVE
FUEL
SCREEN
DASH PUMP
FLOAT
MAIN
AIR
ACCELERATING PUMP
NEEDLE MOVES WITH
AUXILIARY AIR VALVE
A
RANGE ADJUSTMENT 20-40 M.P.H
SCREW OUT IN COLD WEATHER
FOR FULL POWER
THIS CAM RAISES
NEEDLE ENRICHING
MIXTURE
DASH CONTROL
RAISES NEEDLE
SCHEBLER
INDIANAPOLIS
U.S.A.
IDLING
ADJUSTMENT
B

Figure 69, A and B.—Schebler carburetors

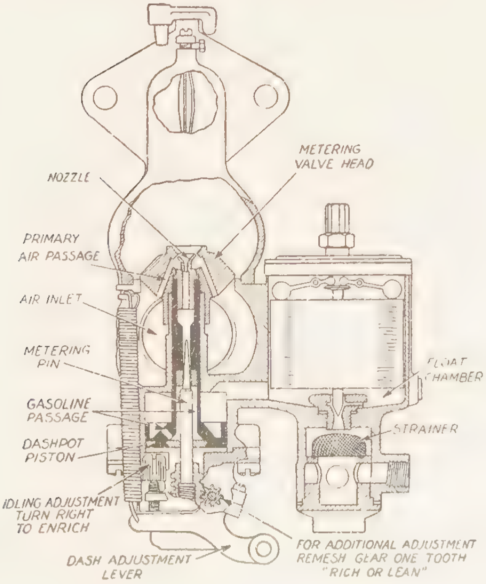

METERING
VALVE HEAD
NOZZLE
PRIMARY
AIR PASSAGE
AIR INLET
METERING
PIN
FLOAT
CHAMBER
GASOLINE
PASSAGE
STRAINER
DASHPOT
PISTON
IDLING ADJUSTMENT
TURN RIGHT
TO ENRICH
FOR ADDITIONAL ADJUSTMENT
REMESH GEAR ONE TOOTH
"RICH OR LEAN"
DASH ADJUSTMENT
LEVER

Figure 70.—Stewart carburetor

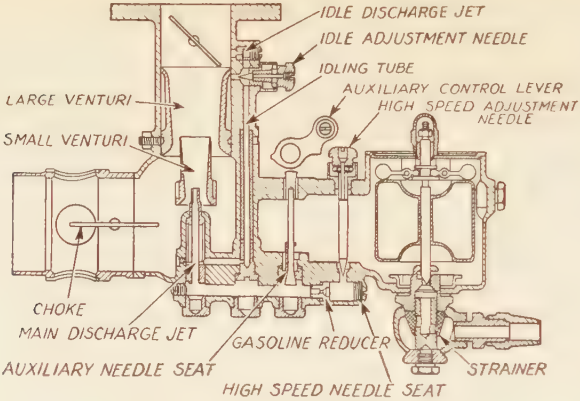

IDLE DISCHARGE JET
IDLE ADJUSTMENT NEEDLE
IDLING TUBE
AUXILIARY CONTROL LEVER
HIGH SPEED ADJUSTMENT NEEDLE
LARGE VENTURI
SMALL VENTURI
CHOKE
MAIN DISCHARGE JET
GASOLINE REDUCER
AUXILIARY NEEDLE SEAT
STRAINER
HIGH SPEED NEEDLE SEAT

Figure 71.—Stromberg carburetor

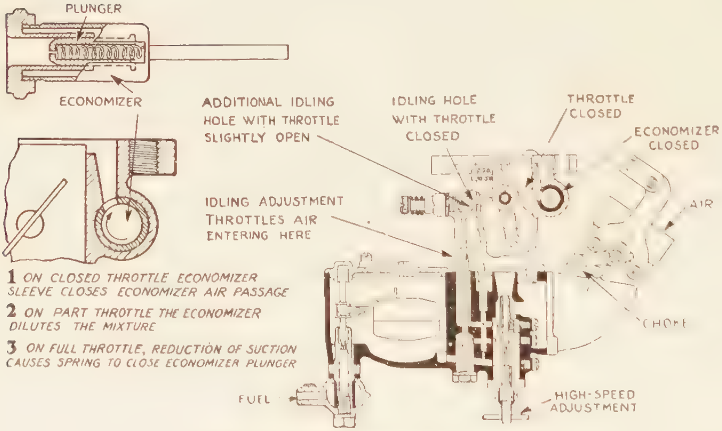

PLUNGER
ECONOMIZER
ADDITIONAL IDLING HOLE WITH THROTTLE SLIGHTLY OPEN
IDLING HOLE WITH THROTTLE CLOSED
THROTTLE CLOSED
ECONOMIZER CLOSED
AIR
IDLING ADJUSTMENT THROTTLES AIR ENTERING HERE
CHOKE
1 ON CLOSED THROTTLE ECONOMIZER SLEEVE CLOSES ECONOMIZER AIR PASSAGE
2 ON PART THROTTLE THE ECONOMIZER DILUTES THE MIXTURE
3 ON FULL THROTTLE, REDUCTION OF SUCTION CAUSES SPRING TO CLOSE ECONOMIZER PLUNGER
FUEL
HIGH-SPEED ADJUSTMENT

Figure 72. Tillotson carburetor

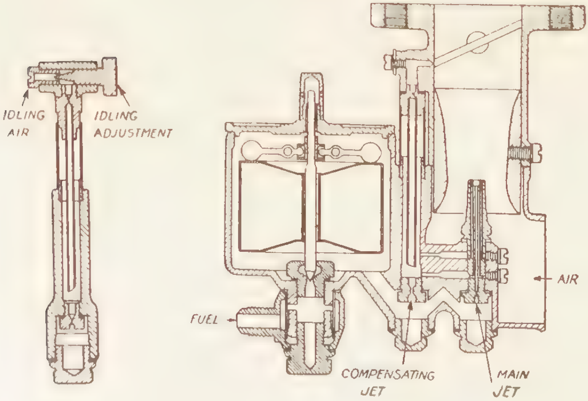

IDLING AIR
IDLING ADJUSTMENT
AIR
FUEL
COMPENSATING JET
MAIN JET

Figure 73.—Zenith carburetor

CARBURETOR LEAKAGE

942. Symptom—carburetor leaks.

943. Causes—(1) Dirt on float valve seat. (2) Float valve stuck open. (3) Float soaked with gasoline. (4) Fuel level too high. (5) Float valve worn.

944. Cure—1. Press float needle down in its seat and rotate a few times to dislodge any dirt which may cause leakage. If trouble continues, drain carburetor; if it still continues, shut off gasoline and remove float mechanism and examine it. A temporary cure against leakage is to shut off the gasoline when the engine is stopped.

945. Cure—2. Examine float mechanism carefully for cause of sticking.

946. Cure—3. If leakage stops when valve is held shut, remove float and examine. If cork float, put in warm oven for several hours to drive off gasoline and then shellac. If metal float, shake it, and if there is any liquid inside, put the float in hot water, escaping bubbles will show the hole. Drill a small hole in the float to allow the fuel to flow out, and if necessary, drill a second hole to permit air to flow in to allow the fuel to flow out. Solder all holes, using as little solder as possible.

947. Cure—4. The fuel level may be too high as indicated in cure 3. Other causes of high fuel level include worn or bent flow mechanism. Replace any worn parts and straighten any parts that are obviously bent.

948. Cure—5. If the float valve is badly worn, as indicated by unabated leakage when the valve is held closed, grind the valve into its seat as described in paragraph 631, or put in a new needle valve and seat.

Chapter X

DOWN-DRAFT CARBURETORS

1001. Two new carburetors, the Holley and the Stromberg, feature a new principle in carburetion known as "down-draft." By contrast, the common carburetor is of the up-draft type.

THE HOLLEY CARBURETOR

1002. Mounted above the intake manifold, the flow of air and fuel is "down hill" all the way through the carburetor and intake manifold, whereas air and fuel flow upward through the conventional up-draft carburetor, upward through the manifold riser and perhaps upward through the intake manifold as well. Thus in the up-draft carburetor, fuel must be lifted against the force of gravity whereas in the down-draft, gravity assists in transporting the fuel from carburetor to engine (Figure 74). This fundamental difference, slight though it may seem, is said to give a horsepower gain of 15 to 20 per cent, depending somewhat on the engine to which it is applied.

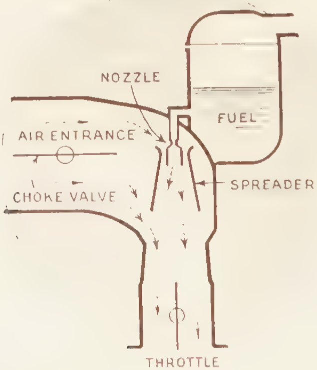


Figure 74.—Principle of the Holley down-draft carburetor. Air flows down through the carburetor and down through the intake manifold into the engine. Fuel flows into the mixing chamber by gravity because the fuel level is above the jet. A spreader assists in mixing fuel and air

1003. In an up-draft carburetor, the fuel must be lifted out of the jet by suction. This means that the throat surrounding the jet must be small enough to provide sufficient suction to pull the fuel out, especially at low speeds and open throttle.

1004. Likewise, at low speeds and open throttle, the velocity of air through the carburetor riser and intake manifold must be great enough to lift the more or less liquid fuel up into the cylinders against the force of gravity. To obtain a sufficiently high minimum air velocity, the cross-sectional area of the intake manifold is made smaller than would otherwise be necessary. Obviously, both the small intake pipe and the restricted carburetor throat prevent the engine from drawing in full charges on open throttle and therefore it does not develop full power.

1005. Also, to assist in distributing the mixture on an up-draft installation, considerable heat must be applied to the mixture, more heat than would be required if the distribution problem were absent. This extra heating expands the mixture, reduces its weight and consequently cuts the power, since power is proportional to weight of mixture delivered to each cylinder.

1006. In the down-draft carburetor, on the other hand, as the flow of air is downward from start to finish, gravity helps carry the liquid fuel particles along with the air. Hence, a larger area intake manifold may be used because transportation of the fuel particles depends to a large extent on gravity instead of solely on air velocity.

1007. The downward slope of the intake passages also makes distribution less of a problem because gravity greatly helps in sending the liquid particles to their proper cylinders. Consequently, it is not necessary to add excess heat to the mixture to assist distribution. On the contrary, it is sufficient to heat the mixture just enough to ensure adequate vaporization within the cylinder by the end of the compression stroke.

1008. The throat area at the jet need not be restricted for small throttle openings because in the Holley, fuel flows out of the nozzle by gravity. Thus by enlarging the path and cutting down the heat the down-draft carburetor adds 15 to 20 per cent to engine power, according to the manufacturer.

PRESSURE DROP

1009. Approximately half the gain in power is due to the fact that the pressure drop in the down-draft intake manifold is considerably less than in the up-draft type. The other half of the power increase is the result of using a smaller hot spot which in turn heats the mixture less than in the conventional intake manifold. It is obvious that the lower the mixture temperature the more it weighs and therefore the more power it develops.

1010. Some data obtained from the Holley Carburetor Co. will make these points clearer: Atmospheric air has a pressure of 14.7 pounds per square inch. In the average up-draft engine running at 3,000 revolutions per minute the pressure in the intake manifold instead of being 14.7 pounds has dropped to about 13.0 pounds. It is this difference in pressure of 1.7 pounds which forces air through the carburetor and intake manifold at a maximum speed of 2½ miles a minute.

1011. In a down-draft engine it is permissible to use larger air passages through the carburetor and intake manifold. Therefore, at 3,000 revolutions per minute the pressure in the intake manifold, by actual measurement, is found to be 14.2 pounds per square inch—that is, only a pressure drop of 0.5 pound (14.7-14.2) is required to force the air and fuel through the intake passages.

1012. The power that an engine develops depends on weight of mixture delivered to the cylinders. Obviously, a down-draft mixture at a pressure of 14.2 pounds weighs more than an up-draft mixture of 13.0 pounds. To be exact, the per cent power gain is the ratio of these two figures 14.2/13.0, or 109.2 per cent, which indicates that the power gain from this advantage is 9.2 per cent. The power increase, of course, would be greater than 9.2 per cent if the up-draft manifold pressure were less than 13.0 pounds, and conversely.

TEMPERATURE DROP

1013. A similar gain in power is obtained by the reduction in mixture temperature incident to the use of the down-draft manifold and this is why. If atmospheric air temperature is 80 degrees, mixture temperature in an up-draft manifold on an engine running 3,000 revolutions per minute will be about 115 degrees, while the mixture temperature in a down-draft engine will be below 70 degrees. The mixture is actually cooler than the entering air because the cooling effect of mixture evaporation more than offsets the heating effect of the small hot spot.

1014. Recall that the power an engine produces depends on the weight of mixture entering the cylinders and since any gas expands when heated and thus becomes lighter, it is clear that a mixture at 70 degrees must weigh more than a mixture at 115 degrees.

1015. Before determining exactly how much these temperatures affect mixture weight, it is advisable to digress a moment to note that when we speak of the height of a building we ordinarily mean the height above the street. Thus, if we say a building is 70 feet tall, we mean it is 70 feet from street to roof. But suppose the street is 460 feet above sea level, then the height of the building with reference to sea level is 460 plus 70, or 530 feet.

1016. Likewise, when we say a gas has a temperature of 70 degrees, we mean that we are measuring this temperature from a certain arbitrary temperature level which happens to be 32 degrees below the freezing point of water.

1017. The lowest possible temperature, however, is 460 degrees below the zero mark on the ordinary thermometer. To say this the other way round, when a thermometer registers zero, the temperature is actually 460 degrees higher than the lowest possible temperature. Likewise, a gas at 70 degrees on the thermometer really has a temperature of 70 plus 460, or 530 degrees. Similarly, a gas at 115 degrees has an actual or absolute temperature of 115 plus 460 or 575 degrees.

1018. Now, the weight of mixture in the up- and down-draft manifolds is inversely proportional to these temperatures—that is, the higher the temperature the less the weight. To be exact, the mixture in the down-draft manifold is 575/530 (1.085) heavier than it is in the up-draft manifold, and this results in an 8.5 per cent increase in power. The gain would be greater if the temperature in the up-draft manifold were higher and vice versa.

1019. This power increase of 8.5 per cent may be added to the power gain of 9.2 per cent due to the higher manifold pressure, making the total gain 17.7 per cent for the figures chosen. As previously stated, the actual gain in power on various engines may run from 15 to 20 per cent.

CARBURETOR AIR IS COOLER

1020. Some increase in power is also attributable to the fact that air entering a carburetor placed high is cooler than it is when placed lower. The high position of the carburetor makes both carburetor and valves more accessible. Easier starting is another advantage urged for the Holley down-draft carburetor, because the flow of mixture is continuously down grade.

DETAILS OF CONSTRUCTION

Figure 75 is a plan of the Holley carburetor and gives the position of the sectional views shown in Figures 76,*A* to 76,*D* inclusive.

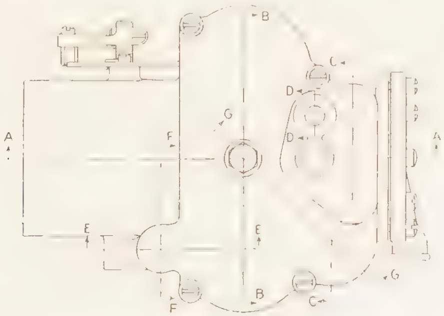


Figure 75.—Plan of Holley carburetor showing position of Sections A A to G G shown separately as Figures 76, *A*, *B*, *C*, and *D*

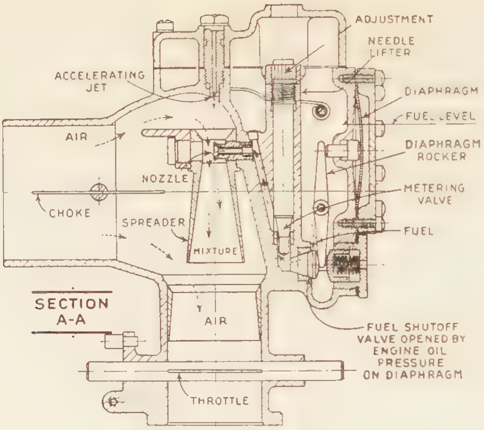

ADJUSTMENT
NEEDLE LIFTER
ACCELERATING JET
DIAPHRAGM
FUEL LEVEL
AIR
DIAPHRAGM ROCKER
NOZZLE
METERING VALVE
CHOKE
SPREADER
FUEL
MIXTURE
SECTION A-A
AIR
FUEL SHUTOFF VALVE OPENED BY ENGINE OIL PRESSURE ON DIAPHRAGM
THROTTLE

Figure 76, *A*.—Section A-A of Figure 75

1021. Two floats (Figure 76, *B*), one each side of the main nozzle, assure a constant fuel level at the nozzle regardless of car tilt. The inverted needle valve (Figure 76, *C*), is actuated direct by a cam on the float shaft.

1022. A single main nozzle (Figures 76, *A* and *B*), supplies all fuel except for starting and acceleration. Fuel flows from this nozzle by gravity because the float level is about half an inch higher than the nozzle, with increasing air velocity as the throttle is opened, suction on the nozzle increases, assisting gravity to deliver more and more fuel.

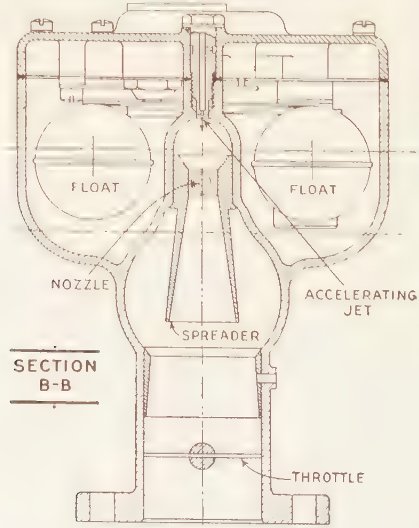

FLOAT
FLOAT
NOZZLE
ACCELERATING JET
SPREADER
SECTION B-B
THROTTLE

Figure 76, *B*.—Section B-B of Figure 75

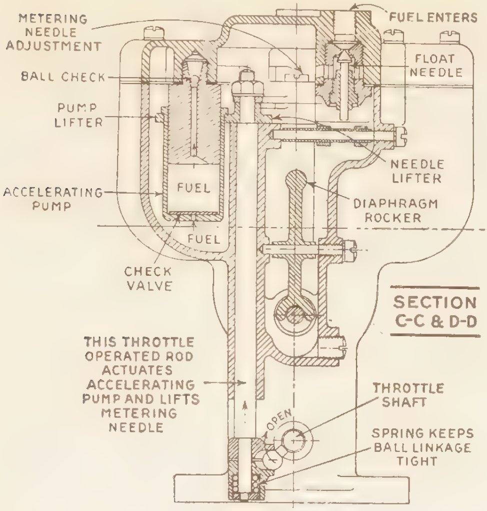

METERING NEEDLE ADJUSTMENT
FUEL ENTERS
FLOAT NEEDLE
BALL CHECK
PUMP LIFTER
NEEDLE LIFTER
ACCELERATING PUMP
FUEL
DIAPHRAGM ROCKER
FUEL
CHECK VALVE
SECTION C-C & D-D
THIS THROTTLE OPERATED ROD ACTUATES ACCELERATING PUMP AND LIFTS METERING NEEDLE
OPEN
THROTTLE SHAFT
SPRING KEEPS BALL LINKAGE TIGHT

Figure 76, *C*.—Sections C-C and D-D of Figure 75

1023. A metering valve in the main nozzle supply line (Figure 76, *A*), controls flow of fuel according to throttle opening, the needle being lifted by a rod actuated by a ball-ended lever on the throttle shaft (Figure 76, *C*). This device gives a lean economical mixture for part throttle and a rich powerful mixture for full throttle.

1024. The foregoing lifting mechanism also operates the accelerating pump (Figures 76, *C* and *D*).

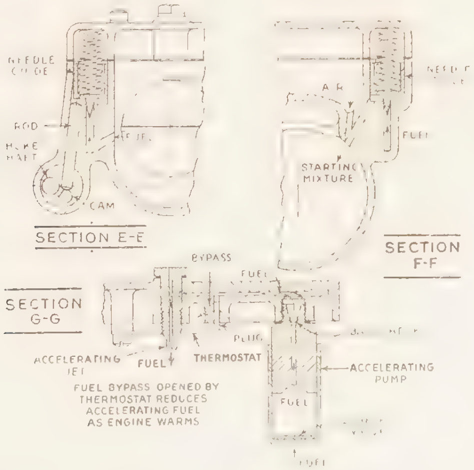

NEEDLE GUIDE
ROD
CHOKE SHAFT
FUEL
CAM
SECTION E-E
AIR
FUEL
STARTING MIXTURE
SECTION F-F
BYPASS
FUEL
SECTION G-G
PLUG
ACCELERATING JET
FUEL
THERMOSTAT
ACCELERATING PUMP
FUEL
FUEL BYPASS OPENED BY THERMOSTAT REDUCES ACCELERATING FUEL AS ENGINE WARMS
FUEL

Figure 76, *D*.—Sections E-E, F-F, and G-G of Figure 75

1025. A thermostat (Figure 76, *D*), opens a plug valve in the accelerating fuel line as the engine warms, reducing amount of fuel delivered to accelerating jet.

1026. A diaphragm-operated valve (Figure 76, *A*), controlled by engine oil pressure, shuts off fuel to main nozzle when engine stops, opening again when engine starts, thus preventing loss of fuel from main nozzle by gravity flow, when engine is stopped.

1027. For starting, the closing of the choke lifts a rod (Figure 76, *C*), which opens a needle valve (Figure 76, *D*), allowing fuel with some air to flow directly into the mixing chamber. Not only does this feature assist in the operation of a cold engine, but also this source of mixture is available before oil pressure has opened the diaphragm valve leading to the main nozzle.

1028. The Holley down-draft carburetor has no auxiliary air valve or compensating jets. When air velocity through the carburetor is at a minimum and there is negligible suction on the nozzle, fuel is supplied solely by gravity flow. As the air velocity increases, the resultant suction pulls an increasing amount of fuel from the nozzle. This action would provide too rich a mixture for maximum air velocity were it not for the fact that at this time a greater proportion of the air flows directly from air entrance to throttle chamber, thus relatively reducing air velocity past the nozzle, and relatively reducing fuel flow so that the mixture is correct.

THE STROMBERG CARBURETOR

1029. To enable the reader to grasp easily the details of the Stromberg down-draft carburetor, the description of the accompanying sectional drawings (Figure 77) is divided into the following parts: (1) Idling jet; (2) Accelerating jet; (3) Main jet. The external views indicate the position of the sectional views. *Note that in any down-draft carburetor the throttle is below the mixing chamber while the choke is above.*

1030. With throttle closed (Section B-B), air flows around the right end of the throttle as shown, producing a suction on the idling passage which is also shown in Section C-C. In the latter view, an adjustable quantity of air flows past the needle valve while fuel is drawn out of the tube which connects with the idling metering jet. When the throttle is opened, suction on the idling jet becomes negligible and it ceases to function.

1031. The accelerating pump is actuated by the decrease in intake manifold suction occurring when the throttle is opened. The complete mechanism (Section E-E), consists of an accelerating pump (right) which is actuated through a rocker by a suction-controlled piston (left).

1032. With throttle closed, the high intake manifold suction acts through a passage running to the inside of the suction piston, overcoming the tendency of the coil spring to thrust the piston upward, and holding it down against the stop rod.

1033. When the throttle is opened, the reduced suction permits the coil spring to move the (left) piston upward, and the rocker arm consequently pushes the accelerating cylinder downward. This cylinder is full of fuel except for some air and fuel vapor at the upper end.

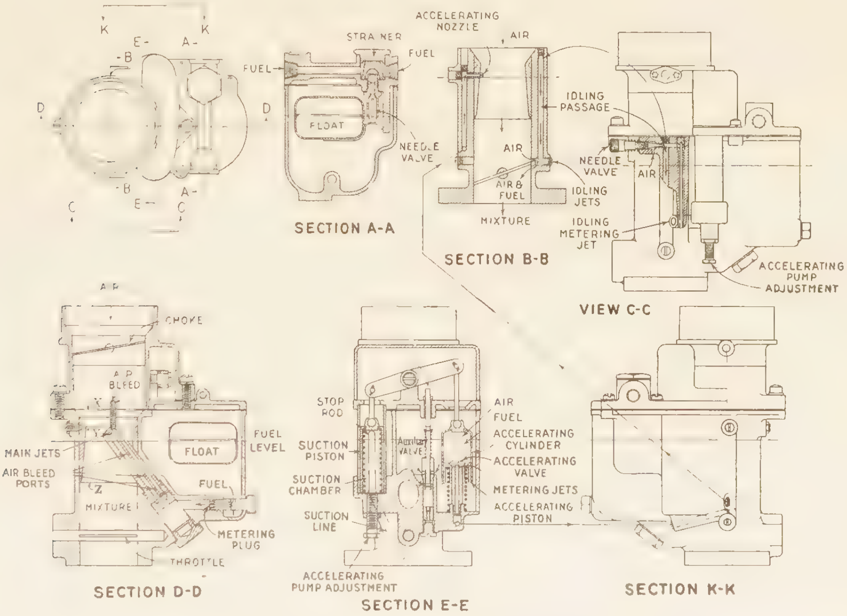

K
K
E-
A-
-B
D
D
-B
A-
E-
C
C
FUEL
STRAINER
FUEL
FLOAT
NEEDLE VALVE
SECTION A-A
ACCELERATING NOZZLE
AIR
IDLING PASSAGE
AIR
AIR & FUEL
MIXTURE
NEEDLE VALVE
AIR
IDLING JETS
IDLING METERING JET
SECTION B-B
ACCELERATING PUMP ADJUSTMENT
VIEW C-C
AIR
CHOKE
AIR BLEED
X
Y
MAIN JETS
AIR BLEED PORTS
Z
FLOAT
FUEL LEVEL
FUEL
MIXTURE
METERING PLUG
THROTTLE
SECTION D-D
STOP ROD
SUCTION PISTON
SUCTION CHAMBER
SUCTION LINE
Auxiliary VALVE
AIR
FUEL
ACCELERATING CYLINDER
ACCELERATING VALVE
METERING JETS
ACCELERATING PISTON
ACCELERATING PUMP ADJUSTMENT
SECTION E-E
SECTION K-K

Figure 77.—Details of Stromberg down-draft carburetor

1034. When the cylinder moves down, it applies pressure to the fluids within it, forcing the accelerating piston down, thus uncovering metering jets in the conical valve and permitting fuel to flow down through the central passage and up through another passage (as shown by the arrows) to the jet (Section B-B), where it is discharged into the carburetor throat. Accelerating fuel continues to flow until the coil spring has forced the piston back up against the conical valve thus closing the passage.

VENTURI PRINCIPLE

1035. Before describing the action of the main jet it is necessary to explain briefly the principle of the venturi, for although nearly all carburetors have a venturi throat it is nevertheless probable that many readers do not understand its action. Section D-D shows that the venturi consists of a smoothly sloped restriction in the air passage. The area at the throat is considerably less than it is an inch or so above or below. As the same quantity of air is flowing through all points of this passage it is obvious that it must flow faster as the passage becomes narrower. In passing from *X* to *Y* the air must accelerate considerably. There is only one thing which will provide acceleration and that is a force or pressure. The only force available is the pressure of the air itself which is, let us say, 14.7 pounds per square inch at *X*. The air expends some of its pressure in accelerating itself and thus the pressure is somewhat less at *Y* than it is at *X*. Most of this drop in pressure is regained as the passage widens from *Y* to *Z*, the resulting deceleration bringing the pressure practically back to normal.

1036. The drop in pressure between *X* and *Y* is slight when the air velocity is small, but as the air velocity increases the drop in pressure grows larger until it is fairly high when the engine is running 3,000 revolutions per minute with throttle wide open.

1037. Let us see how this fact affects the action of the main jets: Fuel flows from the float chamber through the metering plug and thence to the two horizontal holes which constitute the main jet. Section D-D. At low air velocity the pressure drop at the throat is small and so very little fuel flows out. As the air velocity increases, the pressure drop, or suction increases and more and more fuel flows.

1038. It is well known, of course, that if the metering plug is the correct size for proper mixture at low air velocity, it will provide too rich a mixture at high air velocity. On the other hand, if the metering plug size were correct for perfect mixture at high air velocity it would not permit sufficient fuel to flow to give a good mixture at low air velocity.

1039. And as the metering plug is proportioned for low air velocity, something must be done to retard the flow of fuel at higher air velocities. To this end, an air-bleed compensating jet is added as shown. The air bleed communicates with a long diagonal passage in the jet body, there being three holes between this passage and the passage which runs to the main jet.

1040. With throttle closed, the two passages are full of fuel. As the throttle is opened and the air velocity increases the increasing suction at *Y*, or more properly the increasing pressure drop between *X* and *Y*, causes air to flow in through the air bleed and flow out through the main jet, this action naturally reducing the amount of fuel issuing from the main jet since the air dilutes the fuel. With still greater pressure drop, air entering the bleed uncovers the second communicating hole, and with maximum pressure drop the third hole is uncovered. This progressive action prevents too much fuel from flowing and thus provides a proper mixture. As a matter of fact, this compensating jet mechanism has purposely been designed to give maximum economy of operation.

1041. With throttle closed there is no suction on the main jets and the jet body is full of fuel. Consequently, if the throttle is then opened wide the resultant venturi action previously described empties the fuel in the jet body into the mixing chamber. This extra shot of fuel assists in acceleration, being in addition to that delivered by the accelerating pump.

1042. For maximum power on open throttle a richer mixture is desirable and this is secured by opening up an additional fuel lead to the main jet. Recall that except on open throttle all fuel to the main jet is metered by the plug shown just below the float in Section D-D.

1043. However, when the throttle is opened wide, the resulting drop in manifold suction allows the spring to force the suction piston up all the way (Section E-E), and this causes the rocker arm to open the plunger-operated valve, allowing fuel to flow down past the valve through the passage, on into the annular groove in the base of the main jet body (Section D-D), whence it flows to the main jet.

Chapter XI

THE ELECTRICAL SYSTEM

1101. The pages following briefly describe the construction of the starting, lighting, and ignition system. This information is helpful in caring for and finding trouble in the electrical system, but is not absolutely essential, consequently, readers who wish to use this volume only as a handbook may skip this discussion.

1102. Before taking up the complete electrical system, it is necessary to emphasize the fact that there is nothing incomprehensible about electricity as applied to the motor car. The system is as easy to understand as the plumbing system in a house. Wires take the place of water pipes, and although it is true that you can not see electricity flow, neither can you see water flow when it is inside a metal pipe.

1103. It is also helpful to remember that all electrical troubles are in the last analysis, mechanical troubles. Nearly all electrical troubles are caused by loose, dirty, or broken connections, or by short-circuits or grounds caused mainly by rotted insulation. From this description it stands to reason that most causes of electrical trouble are visible, and it is a fact that a pair of sharp eyes when looking for electrical trouble are almost as good as a book full of knowledge. Also, most electrical troubles may be avoided by keeping all connections clean and tight, and repairing insulation defects with tape.

WIRING

1104. The wiring system on the average car looks like a Chinese puzzle to the uninitiated, yet all car-wiring systems follow the same system of arrangement, and once this is understood, any wiring diagram becomes clear at a glance. To understand the principle it is necessary to recall that there are two ways of connecting up electrical apparatus, in series and in parallel.

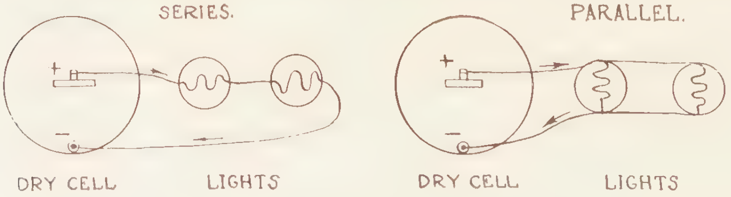


Figure 78.—Lamps connected in series (left) and in parallel (right)

Figure 78 shows two lamps connected to a dry cell, in series (left) and parallel (right).

1105. Similarly, the *major units of every starting, lighting and ignition system are in parallel* (Figure 79). The major units include, starting motor, horn, storage battery, generator, lights, and the low-tension side of the ignition system. Minor control units, such as switches are in series with the major units which they control.

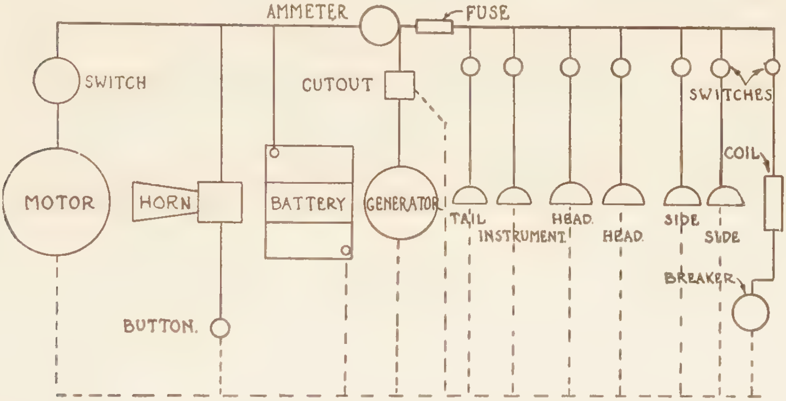


Figure 79.—The major units in every starting, lighting, and ignition system are connected in parallel, while the minor units are in series with the major units

1106. Current is supplied to the whole system, including the battery by the generator when it is charging; when it is not charging, the battery supplies current to the whole system. In most modern cars the engine and frame are made to function as the return wire; this is indicated by the dotted lines. In other words, all major units are grounded.

1107. In actual practice, Figure 79 is modified slightly, as shown in Figure 80, but the principle is not altered; all major units are still in parallel. The most important change is that ignition and lighting switches are shown combined in one housing.

STARTER

1108. When the starting switch, points *4-5*, is closed current flows from the battery through points *3*, *4*, *5*, *6*, through engine and frame to point *1* and then to point *2*. The connections show that starter current is not indicated on the ammeter.

1109. The starting motor gearing usually meshes with teeth on the flywheel, although there are a few exceptions. The Bendix starter drive is used in most cars (Figure 81), and consists of a pinion gear mounted on a spirally cut extension of the starting motor shaft. When the starter switch is closed the motor armature suddenly begins to rotate and the pinion is quickly "screwed" into mesh with the teeth on the flywheel. When the engine starts running instead of driving the starting motor along with it, it screws the pinion back out of mesh.

1110. On machines not provided with the Bendix type drive, movement of the starter pedal slides gears into mesh, the tendency of the engine to run away with the motor, being prevented by the use of an *over-running* clutch which permits the starting motor to drive the engine but does not permit the engine to drive the motor. On Dodge cars prior to 1926, the motor-generator

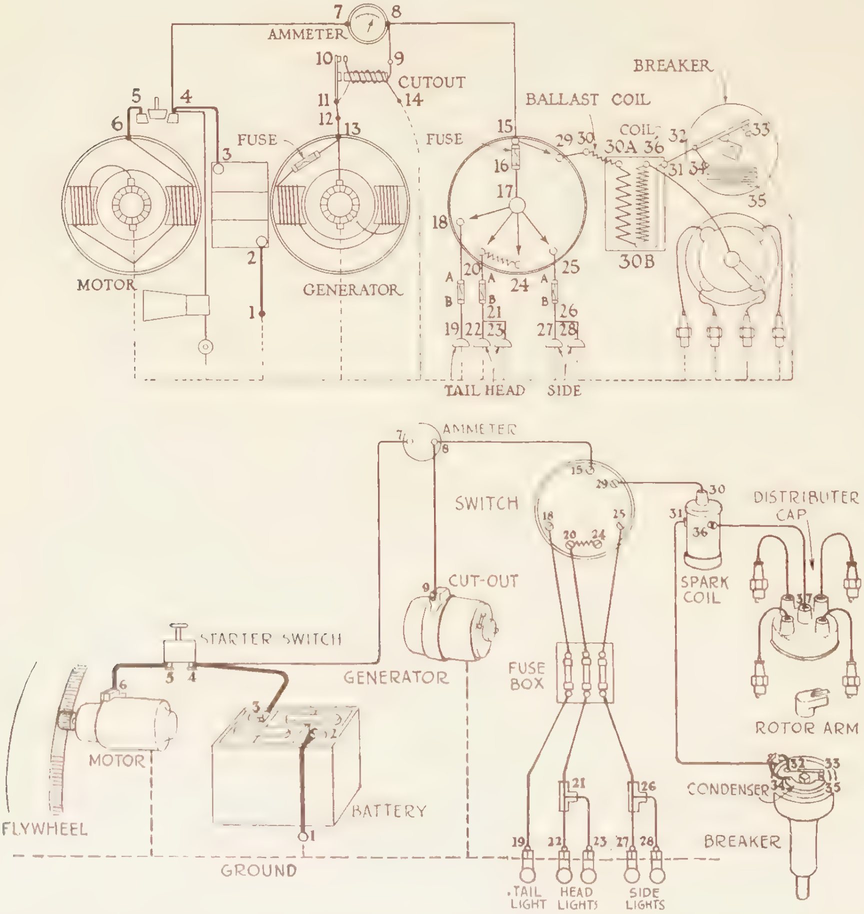

7
8
AMMETER
10
9
CUTOUT
11
14
12
13
5
4
6
3
FUSE
FUSE
15
BREAKER
BALLAST COIL
COIL
29 30
30A 36
32
33
31 34
35
16
17
18
2
MOTOR
GENERATOR
1
20
25
24
A
B
21
26
19 22 23
27 28
30B
TAIL HEAD
SIDE
AMMETER
7
8
SWITCH
15
29
18
25
20 24
30
31
36
DISTRIBUTER CAP
SPARK COIL
37
CUT-OUT
9
STARTER SWITCH
5 4
6
3
1
GENERATOR
FUSE BOX
MOTOR
FLYWHEEL
BATTERY
ROTOR ARM
32 33
34 35
CONDENSER
BREAKER
GROUND
21
26
19
22
23
27
28
TAIL LIGHT
HEAD LIGHTS
SIDE LIGHTS

Figure 80.—These simple wiring diagrams are typical of all modern starting, lighting, and ignition systems, almost identically representing the wiring arrangements on a large number of cars. The major units are in parallel. The lower diagram shows the same parts as the upper one

is connected to the crankshaft by a silent chain, and runs continuously with the engine, but its speed is never excessive, as it only runs three times as fast as the engine, whereas few separate starters run less than ten times as fast.

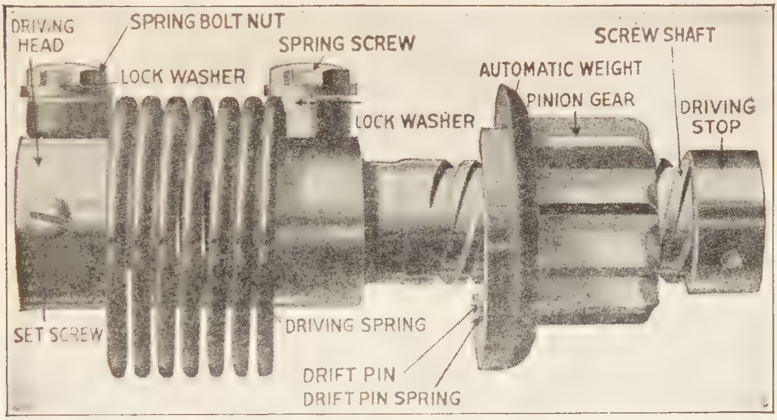


Figure 81.—Typical Bendix drive construction

IGNITION SYSTEM

1111. When the ignition switch is turned on current flows through points *3, 4, 7, 8, 15, 29, 30, 30A, 30B, 31, 32, 33,* (Figure 80), and thence by ground back to points 1 and 2. As the current passes through the ammeter points *7-8*, a discharge reading of 1½ to 3 amperes is recorded. The ignition switch is indicated by the arrow, points *15-29;* a ballast coil is usually placed between points *30-30A*, as shown; points *30A-30B* indicate the low-tension winding of the ignition coil (refer to paragraphs 47 to 54). The breaker points are at *33* with the stationary point grounded; in some cars the breaker arm is grounded and the stationary point is insulated. The condenser connected between points *34* and *35* prevents sparking at the breaker points when they separate. Point *35* on the condenser is grounded. The ballast coil prevents injury to the spark coil by automatically limiting the flow of current with ignition switch on and engine stopped with breaker points closed. Spark coils without a ballast coil are likely to be injured beyond repair under the circumstances described.

1112. The high-tension winding is between points *30B* and *36*. Actually, although the diagram does not show it, the low-tension winding is cylindrical in shape and is surrounded by the high-tension winding. The combination of these two windings is called an induction coil, or more commonly, a spark coil. Before describing how the spark coil works it is necessary to explain that whenever an electric current flows through a wire, a field of magnetic influence surrounds that wire; therefore, when a current flows through the low-tension winding a magnetic field is produced which permeates the high-tension winding. When the breaker points separate, current stops flowing in the low-tension winding, and the magnetic field dies down. Without going further into details it may be stated that the sudden contraction of the magnetic field induces a high-voltage current in the high-tension winding, and this current flows through point *36* to the rotor arm, thence to one of the spark-plug terminals, where it flows down the central electrode, jumps the gap between the points and then flows through the spark-plug shell, the engine and car frame back to point *1,* thence returning to point *30B* by way of points *2, 3, 4, 7, 8, 15, 29, 39, 30A.*

LIGHTS

1113. If headlights and tail-lights are switched on with engine stopped, current flows through points *3, 4, 7, 8, 15, 16, 17* and goes through points *18* and *19,* to the tail-light and through points *20, 21, 22,* and *23* the headlights, whence the current returns by ground to points *1* and *2.* The arrows radiating from point *17* indicate switch contacts. If the headlights are provided with a dimmer resistance, as indicated between points *20* and *24,* dim headlights may be obtained by moving the switch to connect points *17* and *24* without connecting points *17* and *20,* in which case the flow of current through the resistance dims the headlights, bright headlights being obtained by disconnecting points *17* and *24* and connecting points *17* and *20.* Bright and dim headlights may also be obtained by connecting points *17* and *24* for dim headlights and maintaining this connection, but also connecting points *17* and *20* for bright headlights.

GENERATOR

1114. When the engine is running and the generator is charging the battery, current from the generator flows out through points *13, 12, 11, 10, 9,* to point *8.* Here the current branches. The current required by lights and ignition flows to the right, and the remainder, the surplus, flows to the left to the battery, the ammeter reading charge.

1115. In an elementary book of this character it is hardly advisable to go deeply into the theory of electric motors and generators. It should be sufficient to say that a generator consists of a rotating armature mounted in a housing equipped with coils of wire which produce a magnetic field. The wires on the armature, as they rotate in this magnetic field, produce a current. The current flows out to the copper commutator bars where it is collected by brushes which press against it. Most of this current flows to the external circuit (out through point *13,* Figure 80), but a small part of is sent through the wires which produce the magnetic field. The faster the machine rotates the greater its voltage—within certain limits, but inasmuch as a rather constant voltage must be produced (6 to 8 volts) regardless of speed, some means of voltage regulation must be employed, and most generators use third-brush voltage regulation; a few formerly used a vibrating voltage regulator. A motor is similar in construction to a generator. Any motor may be made to run as a generator or conversely; although this does not mean that a starting motor will make a satisfactory generator, or conversely. It is obvious that if the rotation of an armature produces an electric current, the application of an electric current to this machine should cause the armature to rotate.

1116. Flow of current in any electrical circuit depends on difference in pressure or voltage; therefore the generator will charge the battery as long as its voltage is greater than the battery, as would be the case if the battery voltage were 6 and the generator voltage 7. However, when the generator is running slowly, as when the car is moving less than about 8 miles per hour on high gear, generator voltage is less than battery voltage, and the battery discharges through the generator, tending to run it as a motor. The same will occur to a greater degree with the engine stopped.

REVERSE CURRENT CUTOUT RELAY

1117. Consequently, on most cars there is a reverse current cutout relay, points *9*, *10*, *11*, and *14*, which breaks the circuit automatically when the generator voltage is less than the battery voltage, and closes the circuit automatically when the generator voltage is greater than the battery voltage. The closing of the cutout is indicated by a charge reading on the ammeter and its opening, by a momentary discharge. Some cars, however, are not provided with a cutout, as is noted presently.

1118. Figure 80 is applicable in large measure to all cars, particularly if the fundamental thought that all major units are connected in parallel is kept in mind. Car wiring diagrams, however, vary greatly in appearance from this diagram partly because it is the custom among car builders to arrange the major units in approximately the position they occupy on the car, rather than arrange them logically, as in Figure 80. Other complications in appearance are caused by detail changes which do not affect the parallel principle, even though the actual diagram bears no semblance to Figure 80.

1119. On some older cars equipped with Delco generators a cutout is not used; turning on the ignition switch also completes the circuit between generator and battery. In this case, points *9, 10 11,* and *12* are eliminated, and a wire runs from the generator to a point on the switch which is connected with point *15* when the ignition switch is closed.

MOTOR-GENERATORS

1120. On most cars the starting motor and lighting generator are separate units, but the two units while still separate electrically are combined in one housing on all Delco motor-generator models wherein generator and motor windings and their commutators are mounted on the one armature, but generator and motor gearing are separate. When the engine is running it drives the armature as a generator, but when the starter pedal is depressed and the armature functions as a motor, the generator drive is disconnected by an automatic clutch, and the starting gearing is connected to the flywheel. On the Delco motor-generator the starting switch is dispensed with, current being sent through the motor windings by bringing the motor brushes in contact with the commutator. This is automatically accomplished by depressing the starter pedal, and as soon as the pedal is released the brushes are drawn out of contact with the commutator and the circuit is broken. Brush shifting in place of a starter switch is also used on some Delco starting motors. Another feature of the Delco motor-generator is that it has no cutout, both field and armature windings being brought out to the ignition switch so that when the switch is off both field and armature circuits are broken and when the switch is on, both circuits are connected.

1121. When the generator-battery circuit is closed simultaneously with the ignition switch the generator tends to rotate as a motor. This means that if the generator is belt-driven and the belt is loose or missing, closing of the ignition switch will cause the generator to rotate.

1122. Similarly, on the Delco motor-generator the generator winding acts as a motor when the ignition switch is closed, this action assisting in meshing of the starter gearing when the starter pedal is depressed.

1123. Inasmuch as any generator may be run as a motor and conversely, some cars are equipped with a single unit which functions as both (Figure 80). When the starter pedal is depressed it acts as a motor. As the engine picks up, the motor generator voltage gradually rises from zero until it is high enough to close the cutout and charge the battery. Some complication in tracing connections according to Figure 80 is caused by the fact that starting switch and cutout are combined in the same unit. On some of the earlier Franklin models as well as on some other cars, the motor-generator is connected in circuit by closing the ignition switch, no cutout being used. In this case, whether the unit functions as a generator or as a motor depends entirely on whether it is running fast enough to generate sufficient voltage to charge the battery. Obviously, an engine can not be stalled accidentally with this arrangement, because the unit becomes a motor automatically, cranking the engine as soon as the speed drops below a certain point.

1124. When a current flows through a wire, it heats it more or less, depending on how heavy the current is. If the current is heavy, as when an accidental ground occurs, the wire may become so hot it will burn the insulation surrounding it, or the wire may melt. The amount of current flowing through any wire depends on the pressure (voltage), on the length of wire, the material of which it is made, and its cross-section. The last three items form the *resistance* of the wire to flow of current. A 21-candlepower 6-volt head-lamp bulb requires a current of about 3 amperes, 4-candlepower side lamp a current of about $^{1}/_{7}$ ampere, and a 2-candlepower tail-lamp about $^{2}/_{7}$ ampere. These amperages are halved in earlier Dodge cars having a 12-volt circuit instead of the almost universal 6-volt circuit. The generator supplies the battery with a maximum charging rate of about 15 amperes, and the starter may draw 200 amperes or more from the battery. The various wires in the electrical system must be proportioned to stand these currents without undue heating. On the other hand, they may be quickly ruined if the current flowing through them is excessive.

FUSES

1125. To prevent injury to the various wires it is customary to provide fuses at various strategic points, the wires in the fuses melting and breaking the circuit before damage is done to the remainder of the wiring. A number of cars are simply provided with a main fuse, points *15-16,* while other cars have individual fuses for each lighting circuit, as indicated at *AB,* Figure 80. Main fuses are usually of 15 or 20-ampere capacity and individual fuses, 10 amperes.

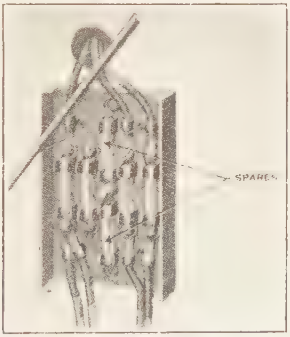


Figure 82.—Cartridge fuses in fuse-box

1126. There are two types of fuses: Link and cartridge. The latter (Figure 82), is a cylindrical type held between spring clips, with the fuse wire within a glass case; the former is a piece of fuse wire with terminals. The fuses may be on the instrument board, on the front of the dash, or in a box on or near the engine. The generator field fuse, if there is one, is usually on the outside of the generator. A cartridge fuse may be defective even when it looks all right. To test, try it in some other circuit. To determine which fuses control certain circuits, remove one fuse at a time, and note what circuit is broken by turning on various lights.

1127. On a number of cars equipped with Delco switches a vibrating circuit breaker is placed at points *15-16* (Figure 80), instead of a main fuse. The circuit breaker begins to vibrate as soon as the current draw is excessive, thus limiting the amount of current flowing through it but not cutting off the lights entirely. On other Delco-equipped cars the vibrating circuit breaker is placed in a separate box, along with a lockout circuit breaker, the former controls the main lights, and the latter such minor circuits as horn, cigar lighter, etc. Units controlled by the lockout circuit breaker are out of action until the ground is removed.

1128. A loose, dirty, or open connection at or between points *1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13* may cause the generator to produce excessive voltage at high speeds, as much as 30 or 40 volts, usually accompanied by a heavy current flow. This may cause the lights to burn out or may burn the field or armature windings of the generator. To prevent this it is customary to install a field fuse in the generator (Figure 80), this fuse burning as soon as the voltage rises beyond a certain point, and thus breaking the field circuit, and rendering the generator inoperative until a new fuse is installed. The new fuse, however, should not be put in until the trouble is found and remedied. It is important to have a fuse of the correct capacity, usually 5 amperes.

FIELD THERMOSTAT

1129. Some Delco-Remy generators are provided with a thermostat which partly takes the place of the field fuse, but it also has an additional function, permitting the generator to charge the battery at twice as high a rate when the engine is cold as when it is warm. When the generator temperature rises above 200 F. the thermostat opens, and thus introduces resistance in the field circuit which halves the generator output. Thus the thermostat protects the generator against excessive voltage caused by a loose connection, but it does not protect any lamps which are on. The main advantage of the thermostat, however, lies in the fact that in cold weather when the car is used mainly for short runs and frequent stops, it permits full charging current to pass to the battery, because the generator rarely becomes warm enough for the thermostat to open. Whereas in summer when long drives are frequent, the engine is soon warm enough to open it, and the generator current is halved, thus largely preventing the battery from being overcharged.

1130. In putting in new bulbs it is important to examine the socket of the old lamp and note whether a single or double contact base is required

(Figure 83); a single-contact lamp will not work in a double-contact socket and conversely. Single-contact lamps are nearly universal, but many cars have one or two double-contact sockets with the remainder single contact, therefore it is advisable to examine the socket in every case. The lamb bulb is removed by pressing in on it and then turning it slightly. Most modern cars use double-filament, double-contact headlight bulbs, each filament supplying 21 candlepower. The filaments are so placed within the bulb, that one filament gives a normal beam, while the other filament gives a depressed beam which does not glare.

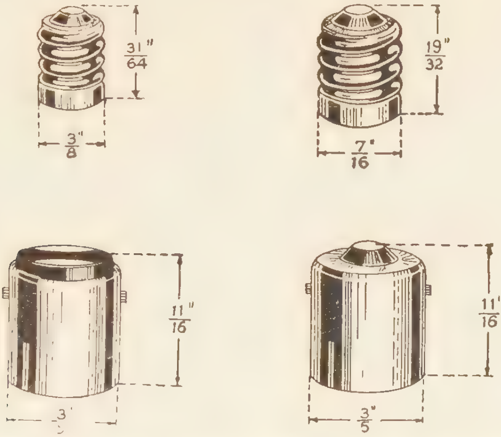


Figure 83.—Miniature lamp bases commonly used. Lower right—single contact; lower left—double contact

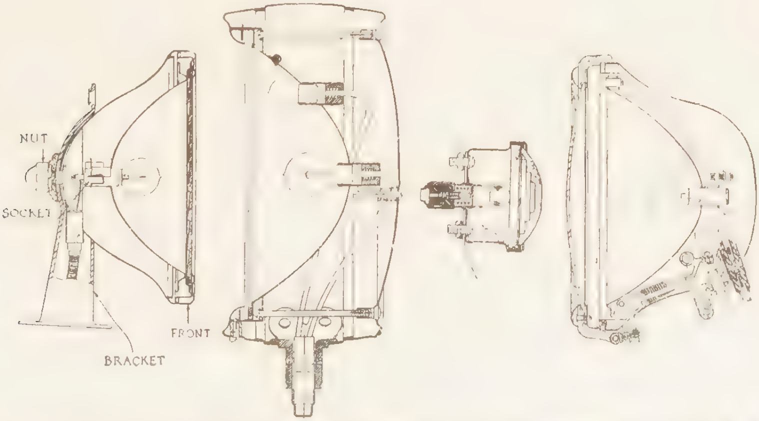


Figure 84. -Head lamps: Left—Studebaker lamp with bulb focused by sliding it in and out. Left center—Jordan head-lamp with small bulb above main bulb. Right center—Jordan tail lamp. Right—Lincoln head-lamp with mechanism for tilting reflector

1131. Head-lamp cover glasses are attached in various obvious ways (Figure 84), usually by some form of hinge and lock, but if the method of attachment is not apparent, to remove the cover, press in on it and then turn it. Note that the path of current through a single-contact bulb is as follows: The current enters the bulb through the central contact in its base, flows through the filament to the cylindrical metal shell surrounding the base, thence it passes through the metal-lamp housing to the lamp bracket to frame.

1132. All head lamps should be properly focused and provided with prismatic cover glasses which prevent the rays of light from straying above the horizontal, although it should be noted that specially shaped reflectors which do not require prismatic cover glasses are sometimes used. Focusing of the bulbs is important not only to obtain full benefit from the light but also to prevent glare. An improperly focused bulb may cause an objectionable glare even with the prismatic cover glass in place.

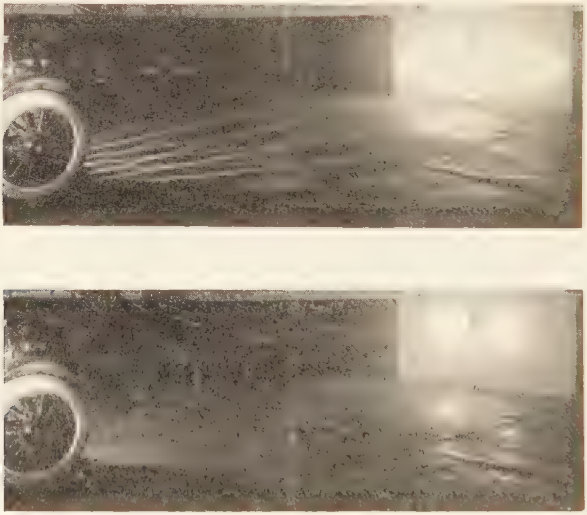


Figure 85.—Focusing head-lamps: Upper—lamps properly aimed and focused with lens-cover glasses removed. Lower—lamps properly aimed and focused with lens-cover glasses in place

1133. Instructions regarding focusing vary somewhat with different cars, but good average results may be obtained as follows: Place the car on a level surface facing a white wall or the equivalent 25 feet away (Figure 85). If the focusing is done in daytime the wall must be screened from any direct light. Measure the distance from the ground to the center of the head lamps and also measure the distance from the center of one head lamp to the center of the other. Mark these points on the wall. Adjust the focus until a horizontal elliptical spot of light is obtained, with sharp contrast around the edges, and so that practically all light rays strike below the points mentioned.

1134. The focus is changed by moving the bulb (Figure 84), closer to or further away from its reflector; this in turn may be accomplished by actually sliding the bulb in and out in its mounting, or by turning a screw at the back of the lamp. Look for the screw first and if none is found, remove the cover glass and move the bulb in or out by hand. Check each adjustment by putting the cover glass back in place, until the best adjustment is obtained.

THE STORAGE BATTERY

1135. It is advisable to remove the screw caps in the cells every two weeks in winter and every week in summer, adding distilled or clean rain water as required. The water level should be kept about ½ inch above the tops of the plates at all times. Do not assume that this frequent inspection is unnecessary just because water is not required every time. More batteries are ruined by failure to add water than through any other cause. In filling the battery it is advisable to use a syringe or a paper funnel; be careful not to spill any water on the exterior of the battery. After filling, screw the caps tightly in place, and wipe off any spilled water.

1136. The normal life of most batteries is 18 to 24 months, although some high-grade batteries will last the life of the car. Therefore, do not be surprised if your battery gives out after 18 months.

1137. The battery terminals should be clean and tight, and as soon as any green corrosion is noticed, the terminals should be wiped clean with a rag dipped in ammonia, and then carefully coated with vaseline. An occasional coat of vaseline thereafter will prevent a recurrence of corrosion.

1138. A fully charged battery is indicated when the horn blows with maximum loudness. On long drives, never turn the headlights on to prevent overcharging of the battery unless the horn is loud.

1139. Every week or so it is advisable to test the gravity of the electrolyte with a syringe hydrometer. If the battery is fully charged, each cell should read 1.270 or above, whereas a badly discharged cell will read 1.150 or below. The variation in the different cell readings should be less than 0.50.

1140. Hydrometer readings taken immediately after filling with water will be low, and readings taken just before filling may be a little too high; the best plan is to take the readings some time after filling the cells. If the car is exposed to freezing temperature, water should not be added except immediately before running the engine, because the charging of the battery helps to mix the water with the acid. If this precaution is not observed, freezing of the water added is likely, with probable damage or ruin of the battery

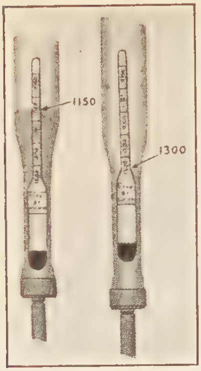


Figure 86. — Battery hydrometer showing high and low readings

The electrolyte in a fully discharged battery readily freezes, almost as readily as pure water, whereas a half-charged battery (with electrolyte reading 1,200) freezes at 16° below zero, and a fully charged battery (electrolyte 1,300) at 96° below zero. Freezing ruins a battery beyond repair.

1141. For those who are unfamiliar with the use of a hydrometer it should be explained that enough liquid is withdrawn from the cell into the syringe to float the indicating bulb (Figure 86), the amount the bulb sinks into the liquid indicating the specific gravity of the electrolyte. Be sure to replace the liquid withdrawn.

BATTERY DISCHARGE

1142. Continued operation of a battery in a half-charged condition, or allowing the battery to stand for a long time half-charged is injurious and should be avoided. Even a fully charged battery, if allowed to stand for several months, as when the car is laid up, will gradually discharge. Consequently, when the car is not to be used for a period of more than a month it is advisable to take the battery to a service station so that it can be charged occasionally during its idle period, thus keeping it in prime condition.

1143. A better plan is to have your battery-man call for the battery, inasmuch as special measures are required to operate the car without a battery, as would be the case in running the car home after the battery has been removed.

1144. If it is ever necessary to run the car without a battery (either your own or a rental battery), ignition may be supplied by connecting four or five dry cells in series—that is, connect the positive terminal of one cell to the negative of the next. One side of the group should be connected to any convenient metal part of the car, and the other side should be connected to point *3*, *4*, *7*, *8*, or *15* (Figure 80), whichever happens to be most convenient. As a rule, point *3* is the easiest to reach. It is essential that the connections be clean and bright and absolutely tight. If the car is equipped with a magneto, the dry cells, of course, are not necessary.

1145. Before attempting to run the engine it is imperative to remove the generator field fuse, if there is one, and if no field fuse is fitted, run a wire from point *13* on the generator to ground—a piece of ordinary lighting wire should be satisfactory, or two strands of iron stove-pipe wire. If the cutout is attached to the generator it must be removed to make this connection. If it is not feasible to take these precautions, drive the car slowly, although even then failure to observe the foregoing instructions is likely to ruin the generator, unless it is protected by a field fuse. If the generator is equipped with a vibrating voltage regulator, remove it if convenient, otherwise drive the car as slowly as possible, but do not ground the generator as described.

1146. In normal use, to keep a battery charged it must be supplied with more current than it gives; in other words, the input must exceed the output, but even then it will be impossible to keep the battery charged if it has any internal defects. In general, a run-down battery is due to too much use of lights and starter. Excessive cranking drains the battery, but this loss is rarely as serious as allowing the car to stand for long hours with two front lights and tail-light burning. It is necessary to run the car for several hours to make up the current consumed by these three lights. It is not safe to park the car without lights at night on a public highway, therefore the solution is either to keep it off the highway or install a parking light; this is a single light usually mounted on the right front or rear fender; it takes a 2-candlepower bulb, showing a white light forward and a red light to rear.

1147. A discharged battery may also be due to some defect in the generator which prevents it from supplying full charging current, or to leakage of current between battery and generator due to a ground.

1148. If the battery can not be brought back to normal condition with strictest economy in the use of lights and starter, it should be taken to a garage or battery service station and given a bench charge. When possible, take your battery to a battery or electrical service station. Although most garages have charging equipment, they are not always in a position to render the expert service that is often required. Sometimes a prolonged charge lasting for two or three days may be necessary to bring the battery back to normal; in other cases it will be found that the battery is in need of repair, or beyond repair. The cost of a new battery is now so low, as compared to cost of repairs, that it is usually better to buy a new battery than to have the old one repaired.

1149. If there is more than 50 points variation in the reading of the different cells, a battery-man should be consulted.

1150. If one cell habitually requires more water than the others, this cell is defective or its battery jar is cracked. See your battery-man.

1151. If the gravity of one cell is low and normal in the other two, it is not likely that the battery will have sufficient ability to crank the engine, although it may provide bright lights. Consult your battery-man.

1152. The battery should be securely fastened in place to prevent injury through jolting. In removing or replacing battery terminal connections, do not use force, or you are likely to break the battery cell jars.

1153. When a battery is removed it is important to scratch a mark on the terminals so that when it is replaced the terminal cables are connected the same as before removal.

1154. The rated voltage of a battery is indicated by the number of cells, 2 to 2.5 volts per cell (Figure 87).

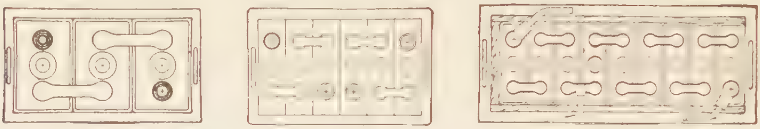


Figure 87.—Storage-battery cells: Left—6-volt; center—12-volt; right—18-volt

THE IGNITION SYSTEM

1155. On all high-tension ignition systems (except that used on the Ford Model T, see paragraph 1701) the mechanism consists of two principal parts, the breaker and the distributor (Figure 88).

1156. The breaker points should meet squarely and be reasonably smooth and clean, and when the points are separated by the cam the gap should be

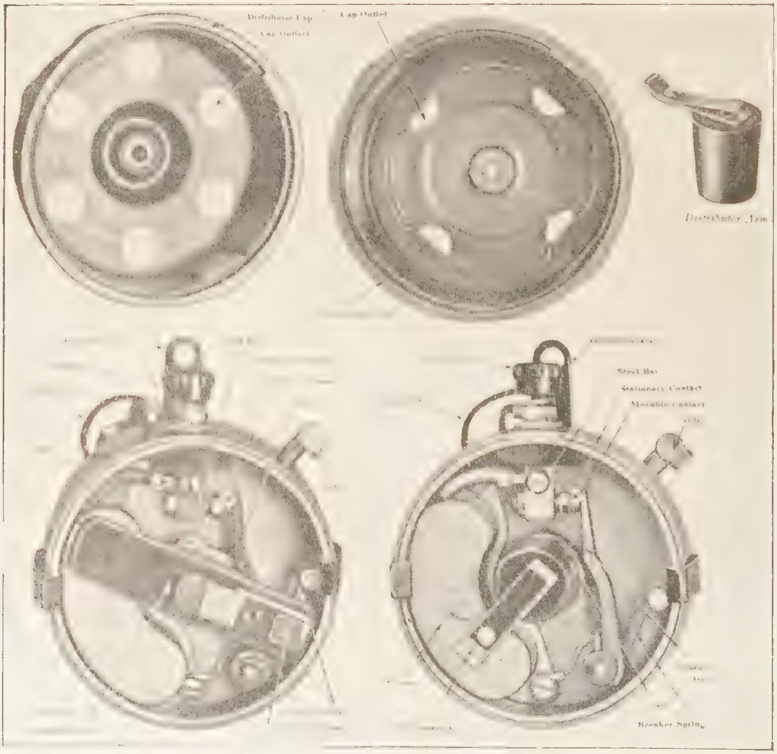

Distributor Cap
Cap Outlet
Cap Outlet
Distributor Arm
Steel Bar
Stationary Contact
Movable Contact
Breaker Spring

Figure 88.—Breaker and distributor: Left—6 cylinders with carbon brush at end of rotor arm; right—4 cylinders with metal piece on rotor arm

about 1/64 inch, although the exact amount varies with different makes of ignition equipment, and also varies somewhat with the same make on different cars.

1157. If the points are too far apart the engine may miss and buck at slow speeds, and may start reluctantly, whereas if they are too close together, missing at high speeds may be observed, with marked loss of power if points are much too close together.

1158. The object, therefore, in adjusting the points is to set them so that the engine runs perfectly at all speeds. If the exact gap recommended by the manufacturer is unknown the best plan is to set the points at 1/64 inch. If the engine starts readily and runs smoothly at slow speed this gap is not too great, but if it refuses to start or bucks or misses at slow speed, the gap must be reduced slightly. On the other hand, if easy starting is obtained but missing is observed at high speed, or if the engine develops less than normal power, the gap is too small. It should also be noted that if the gap is much too small, missing at all speeds and perhaps failure to start may be observed.

1159. The adjustment of the breaker points is a delicate matter, as the fraction of a hair one way or the other may make a great difference, and a good adjustment often requires several trials unless you have a gage to eliminate the guesswork.

1160. The breaker mechanism is usually reached on a battery ignition system by lifting off the distributor cap and the rotor arm. The stationary breaker point is either mounted in a sliding bracket locked by screws, or the breaker point is mounted on the tip of a screw, adjustment being obtained by turning the screw in or out, after the lock-nut or lock screw is loosened. On a magneto the breaker mechanism is on one end of the armature shaft.

BREAKER ADJUSTMENT

1161. To determine the gap accurately the points must be fully open; in other words, the breaker arm must be on the highest point of the cam. This point may be approximately reached by cranking the engine slowly by hand or by placing the car in high gear and pushing it slightly backward or forward until the breaker points are approximately fully open. In either case full opening may then be obtained by advancing or retarding the spark lever. Most eights and twelves and a few sixes have two breakers in the ignition unit. Because of the necessity for accurate action, it is best to have them adjusted by an expert.

1162. After a few thousand miles the breaker points will become so worn that they must be smoothed. This condition is usually accompanied by hard starting, missing, and bucking at slow speeds, and if neglected, is followed by failure of the engine to start. The flow of current between the breaker points removes metal from one point and builds it up on the other causing a mound on one point and a pit on the other. It is only necessary to remove the mound, provided that the pit does not cover more than 25 per cent of the total area of the point; otherwise the pit should be ground down until its area is below 25 per cent. Breaker points are usually made of such hard material that filing is impossible, therefore it is advisable to smooth them on an oil-stone, being careful to wipe off all oil before replacing the points. When the hard metal of which the point tips are made is completely worn off, new points will be required; these should be purchased only from the manufacturer of the equipment or his authorized agent. In an emergency, as with a stalled engine on the road, a mound may be ground off by rubbing it on a fairly smooth, hard stone.

SPARK TIMING

1163. As explained in paragraph 53, the breaker mechanism must be set or timed so that the sparks are sent to the cylinders at the proper instant. To determine whether the spark is properly timed, proceed as follows:

1164. On most engines, the spark is correctly timed if the breaker points are just ready to open when the spark lever is retarded all the way and a piston is on dead center.

1165. The first step is to see that the breaker-point gap is correct or about correct. Then place a piston on dead center. On many engines the flywheel is marked, *D. C. 1,* for example, indicating that piston No. 1 is on dead center when this mark is at its highest position. This position is often indicated by an arrow mounted on the engine (Figure 55).

1166. If there are no marks on the flywheel, the upward motion of the piston may often be observed through a spark-plug opening, or if it can not be observed it may be felt with a stiff wire, upper dead center being reached when the piston is at the top of the stroke.

1167. In roughly checking the spark timing, as when looking for trouble, dead center may be assumed to be the point at which any exhaust valve closes, assuming that the valve is correctly adjusted. If it is necessary to time the spark by this method, excessive spark knocking indicates that the spark is too early and lack of power, perhaps accompanied by overheating, indicates that it is timed too late.

1168. There are various ways of changing the spark timing: The gear which drives the breaker cam may be meshed to give approximately the timing desired usually this is the most difficult method, although sometimes the only one available. In some cars the breaker cam may be adjusted, after loosening a screw in the top of the breaker cam shaft or on the bottom. The upper screw is visible, if there is one, and the lower screw adjustment can only be used when the lower end of the shaft is accessible, as when the ignition unit is mounted vertically at the end of the generator. In many cars the spark-advance crank arm is attached to the ignition unit by a clamp which, when loosened, permits the whole ignition unit to be turned to give the timing desired. Couplings that drive the ignition unit are often adjustable, although used almost exclusively on magnetos. With all these methods, slight variations in adjustment may be obtained by lengthening or shortening the spark-advance linkage.

1169. If, in addition to timing it is necessary to attach the high-tension wires to the correct spark-plugs, proceed as follows: Find out the firing order —that is, the order in which the cylinders fire. If this information is not at hand it may be determined by turning the engine over slowly and watching the opening of all intake and exhaust valves (how to distinguish between intake and exhaust valves is described in paragraph 639). Note the order in which the valves open, as for example, 1, 2, 4, 3 or 1, 3, 4, 2 on a 4-cylinder engine. See paragraph 24.

1170. Bring cylinder No. 1 (or any other cylinder) to upper dead center ready to begin its explosion stroke (both valves closed). If you are timing the spark according to exhaust-valve closing, turn the engine carefully through one complete revolution after the exhaust valve has closed.

1171. The breaker points should now be timed by one of the methods described in the third preceding paragraph. Then put the rotor arm in place and note to which segment it is pointing to on the distributor. Connect No. 1 spark-plug wire to this segment. Note which way the rotor rotates and connect the other spark plug wires according to the firing order. This means that if the firing order is 1, 3, 4, 2, spark-plug No. 1 is connected to the segment to which the rotor is pointing, the next segments in the rotor's path is connected to No. 3 spark-plug; the next to No. 4 spark-plug, and the last to No. 2 spark-plug.

MAGNETO

1172. In principle, the magneto resembles the battery ignition system, and has a breaker and distributor mechanism (Figure 89). It differs mainly in that it generates its own current, by the rotation of its armature. In all

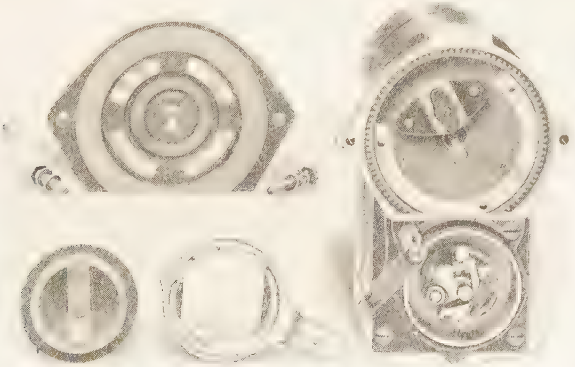


Figure 89.—Details of construction of a typical magneto (American Bosch)

modern magnetos the induction coil is embodied in the machine, either placed on the rotating armature or above it. The treatment of the breaker and distributor are the same as for the battery ignition system, and no repairs to the remainder of the mechanism should be attempted, except by a magneto expert. After a time the magneto magnets may lose their magnetism and require recharging, although in many this will not be necessary for years. This work should be done by an electrical expert. The need for recharging is indicated by difficulty in starting, although before coming to the conclusion that the magnets are weak it is necessary to be sure that the trouble is not elsewhere. See Difficult Starting, paragraph 1522. Ignition is shut off by closing a switch which grounds the low-tension winding.

Chapter XII

STARTING AND LIGHTING TROUBLES

1201. For those who find difficulty in interpreting the wiring diagram (Figure 80), the following descriptive key may be of service in finding the various points mentioned on the car:

CONNECTIONS

1202. Points *1-2:* Cable running from battery terminal to ground on frame or engine. Point *1* represents the connection of the cable to the frame and point *2* the connection of the cable to the battery terminal.

1203. Points *2-3:* The storage battery is connected between these points.

1204. Points *3-4:* Cable running from storage battery to starter switch. Point *3* represents the connection of the cable to the storage battery and point *4* represents the connection of the cable to the starter switch.

1205. Points *4-5:* The starter switch is connected between these points.

1206. Points *5-6:* Cable running from starter switch to starter. Point *5* represents the connection of cable to starter switch and point *6* represents terminal on starting motor.

1207. Points *4-7:* Wire connecting ammeter to battery. Point *7* represents the connection of this wire to ammeter, while the other end of the wire is usually connected to point *4*, although it may be connected to point *3*.

1208. Points *7-8:* The ammeter is connected between these points.

1209. Points *8-9:* Wire running from ammeter to cutout (or from ammeter to switch if there is no cutout). The wire is connected to the ammeter at point *8* and to the cutout (or switch terminal) at point *9*.

1210. Points *9-12:* The cutout is connected between these points.

1211. Points *10, 11,* and *14:* Point *10* represents the cutout points. The series winding of the cutout is connected between points *9* and *10*, and the shunt winding between points *11* and *14,* the latter being grounded. Parenthetically, it must be said that the elementary character of this book makes it undesirable to give full details regarding the cutout, but it is worth stating that the shunt winding closes the cutout and the series winding opens it aided by a spring; all of these connections must be clean and tight.

1213. Points *12-13:* Wire running between cutout and generator, this wire being eliminated if cutout is mounted on generator. Point *12* is a terminal on the cutout and point *13* is the generator terminal.

1214. Points *8-15:* Wire running from ammeter to lighting switch. Point *8* represents the connection of this wire to the ammeter and point *15* the connection to the lighting switch.

1215. Points *15-16:* Main fuse or vibrating circuit breaker. Often this unit is not placed in the lighting switch as shown but is separate from it, but the main fuse (if there is one) is always in the wire running from ammeter to lighting switch.

1216. Points *16-17:* Wire running from main fuse to lighting switch.

1217. Points *17-18, 17-20, 17-24, 17-25:* These are lighting switch points.

1218. Points *18-19:* Tail-light circuit.

1219. Points *20, 22, 23:* Head-light circuit.

1220. Points *25, 27, 28:* Side-light circuit.

1221. Points *20-24:* Dimmer resistance, used only if big bulbs may be dimmed.

1222. Points *A-B:* Individual fuses. The lighting circuits are not always as simple as they appear in the diagram (Figure 80), if individual fuses are used. The three fuses are probably in a fuse box. Therefore the tail-light circuit consists of a wire *18-A* running from switch to fuse box, and a wire *B-19* running from fuse box to tail-light. And similarly for the other lighting circuits.

1223. Points *15-29:* Ignition switch.

1224. Points *29-30:* Wire running from ignition switch to spark coil.

1225. Points *30* to *30-A:* Ballast coil consisting of a few turns of iron or nickel wire adjacent to point *30*. Not all spark coils have a ballast coil.

1226. Points *31-32:* Low-tension wire running from terminal *31* on spark coil to *32* on breaker mechanism of ignition unit.

1227. Points *36-37:* High-tension wire running from spark coil to rotor arm in distributor.

1228. Wires are usually connected to terminals by nuts or screws (Figure 90).

1229. Ordinarily, the wire ends are provided with terminal lugs, but occasionally the ends of the wire are wrapped around the terminal. Loose

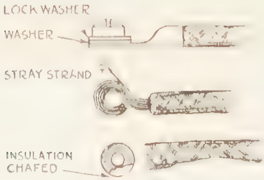


Figure 90

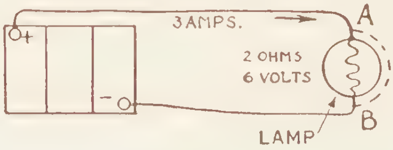


Figure 91

Figure 90.—Wire terminals: Upper—correct wiring connection. Center—stray strands at terminal may cause trouble. Bottom—chafed insulation

Figure 91.—Dotted line indicates a short circuit

connections are due to the retaining screw or nut being loose; dirty connections include connections that are corroded or covered with oil or mud.

1230. A short-circuit is a defect in the circuit which permits the current to take a shorter path as shown by the dotted line (Figure 91).

1231. In speaking of electrical troubles the term *ground* describes a short-circuit between a live wire and ground, as shown at BX, CX, DX, EX (Figure 92), which is a close-up of Figure 80. A ground might occur at any of the points indicated due to chafing or rotting of the insulation thus permitting it to come in contact with some metal part causing a ground. Grounds may also be caused by stray strands of wire coming in contact with uninsulated metal parts. Both of these defects are illustrated in Figure 90. Grounds may also be due to defective insulation in almost any piece of electrical apparatus. It should be noted that the loss of current through a ground causes various defects; these are fully discussed under the various symptoms of starting and lighting troubles.

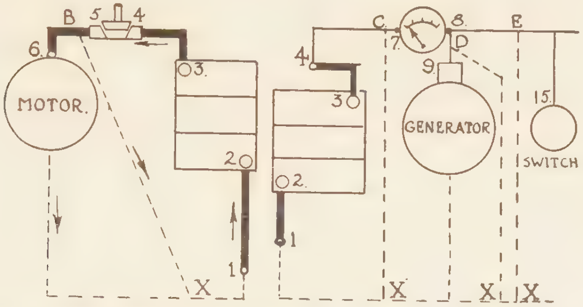


Figure 92.—Dotted lines indicate grounds. This is a close-up of Figure 80

1232. The amperage required by any automobile bulb is approximately equal to the wattage or candlepower rating divided by 7. Therefore, if the candlepower is 21 the amperage the bulb requires is 3. Similarly, a 4-candlepower bulb takes $\frac{4}{7}$ ampere, and a 2-candlepower bulb, $\frac{2}{7}$ ampere. It should also be noted that a bulb develops 1 candlepower for every watt of current consumed, which means that bulbs of 21, 4, and 2-watts rating respectively, give 21, 4, and 2 candlepower. If head, side, and tail-lights are respectively 21, 4, and 2 candlepower, the ammeter discharge with ignition shut off is $\frac{10}{7}$ amperes or approximately 1.4 with side and tail-lights on, and $6\frac{2}{7}$ amperes with headlights and tail-light on. If the maximum charging rate of the generator with all lights off is 15 amperes, the charging rate with head and tail-lights should be $8\frac{5}{7}$ amperes; and with side and tail-lights on, 13.6 amperes. Spotlights and stoplights should have 21-candlepower bulbs, side lights and interior lights generally use 4-candlepower bulbs, instrument board lights and other minor lights are of 2 candlepower.

STARTER CRANKS SLOWLY

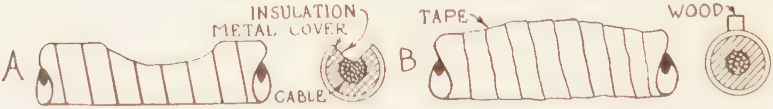
1233. Symptom—Starter cranks slowly.

1234. Causes—(1) Battery weak. (2) Excessive engine friction. (3) Loose or dirty connection or ground in starter circuit, including starter switch, points *1, 2, 3, 4, 5, 6* (Figure 80). (4) Defect within starter.

1235. Cure—1. Switch on lights and then depress starter pedal. If lights grow very dim the battery is weak. (See paragraph 1135). The tone of the horn will also be below normal. Confirm this diagnosis by testing battery with a hydrometer if you have one.

1236. Cure—2. Turn engine over with hand crank to determine whether engine friction is greater than usual. Excessive friction may be due to extremely cold weather, oil too heavy, tight bearings, or piston rings, frozen slush in the water pump or slush in oil pump, badly overheated engine, or a hot engine plus thin or poor quality oil. If the weather is cold, try a lighter engine oil; tight bearings and piston rings will only cause trouble immediately after the engine has been overhauled.

1237. Cure—3. Hold starter switch closed for 15 or 20 seconds, and then touch points *1, 2, 3, 4, 5, 6* (Figure 80), with the fingers. A point that is warm or hot indicates a loose or dirty connection; but do not be misled by heat generated by the running of the engine. Clean any loose connection with fine sandpaper or a file and tighten it carefully. Absolute tightness is especially essential at points *2* and *3*. If no hot points are found, be doubly certain by examining all points for dirt and looseness; clean and tighten as required. Then run the fingers over the wire cables. If the insulation is chafed or rotted at any point, exposing the bare cable, tape this section carefully (Figure 93). Take steps to prevent further chafing by tying the cable away from the member it chafes or if this is not feasible tie a piece of wood between the two parts to take the chafing.



93.—*A*, chafing of starter cable; *B*, cable repaired

1238. If no defects are found, the starter switch may be dirty or making poor contact. Disconnect starter cable at point *5* and touch it firmly to point *1*, being careful to keep the fingers away from the end of the cable to prevent a burn. If the starter now works at normal speed, the defect is within the switch. The switch may be repaired by your repairman, although it is often better to have this work done at an electrical service station. The foregoing test is only conclusive when good contact is made, which means that the contact must be both firm and clean. Do not make this test in the presence of gasoline fumes, because an explosion might result.

1239. Cure—4. If causes, 1, 2, and 3 have been eliminated, the troubles must be within the starting motor. It is not advisable for the motorist to attempt to find and cure the trouble, but the work should be done by an experienced repairman, preferably an electrical expert.

STARTER BALKS

1240. Symptom–Starter balks.

1241. Causes—(1) Defect in starter gearing. (2) Battery discharged. (3) Excessive engine friction. (4) Loose, dirty or open connection or ground. (5) Defect in starter.

1242. Note: The defects which prevent the starter operating are similar to those which cause slow cranking, but of greater intensity.

1243. Cure—1. Close starter switch for a moment. If motor armature spins idly (usually denoted by a faintly perceptible whirr) there is some defect in the gearing. If the car is equipped with a Bendix drive (Figure 81), wash the gear and shaft in kerosene to remove all grease; do not apply any lubricant. Also note whether the Bendix spring is broken. Often it will be necessary to remove the starter to make this inspection. As a rule this may be readily done by removing the cap screws which are in the starter housing flange, and disconnecting the starter cable. Unless the starter gearing is accessible, it is usually best to have whatever work is necessary done by your repairman. A broken Bendix spring should be replaced.

1244. Cure—2. If starting motor cranks engine very slowly for a revolution or more before stalling it probably indicates that the battery is run down. Both in this case, and when the starting motor refuses to move the engine at all, blow the horn. If the tone is much below normal the battery is probably run down. Turn on lights, and close starter switch. If the lights grow very dim the battery is probably run down. If the lights are dim even with the starter switch open, the battery is probably almost completely discharged. Before assuming that the trouble is positively in the battery, try Cures 3 and 4. Then check battery condition with a hydrometer, paragraph 1139.

1245. Cure—3. Crank engine slowly by hand. If engine cranks with great difficulty, excessive friction is indicated, although bear in mind that on a few cars the friction may be entirely in the crank handle, especially if the crank is in poor alinement with the engine due to a weak or broken front spring, a soft tire, or a loose frame cross-member. Also, it may be impossible to crank engine at all, due to binding of parts. The trouble is usually due to one of the following causes:

1246. A. If water in radiator is frozen and the engine is equipped with a pump, the pump may be frozen solid. The engine may be cranked as soon as parts are thawed, although damage to the cooling system may prevent use of engine until repairs are made.

1247. B. If there is water in the oil, the oil pump may freeze solid, especially if it is at the lowest point of the lubricating system. This trouble will disappear as soon as the car is thawed out.

1248. C. If the car has been operated with insufficient water or oil, the engine may have become so hot that the pistons are stuck to the cylinder walls. The trouble may disappear when the engine cools, and then again dismantling of the engine plus extensive repairs may be required. Do not pour cold water into the radiator until the engine cools. Also, if car has been laid up, pistons may be rusted to cylinders.

1249. D. The starter gearing may have broken or jammed. This is especially likely if the failure of the starter occurs immediately after cranking the engine with spark so far advanced that the initial explosion causes the engine to run backward. The engine can be cranked by hand as soon as the starter is removed, provided that no broken pieces have fallen into the flywheel housing. It may be possible to have the broken parts repaired, but more usually new parts are required to replace those broken. Before removing starter, place the car in high and rock sharply back and forth by hand. If the starter is merely jammed this treatment may free it.

1250. Cure—4. Close starter switch for 15 or 20 seconds, and then feel points *1, 2, 3, 4, 5, 6* (Figure 80). A hot point indicates a dirty or loose connection. Clean the contact surfaces with sandpaper, file, or scrape with a knife, and tighten carefully. Points *1*, *2*, *3*, or *4* may be sufficiently loose to prevent the starter working, without appreciably affecting lights or ignition. If not points are found, run the fingers over the cables between points *3* and *6* to find a spot where the insulation has chafed away, allowing the chafed spot to ground on some metal part. A ground in the cable between points *3* and *4* will also cause a discharged battery. For repair, see paragraph 1237.

1251. Disconnect the cable at point *5* and touch it to point *4*. If the starter operates, it indicates that the trouble is within the starting switch. For further details regarding this test, see paragraph 1238.

1252. If no hot point and no ground is discovered, the trouble may be due to a connection which is actually broken or so loose or dirty that practically no current can flow. Therefore, points *1, 2, 3, 4, 5, 6,* should be examined again carefully. Points *1*, *2*, *3*, *4* may be eliminated if the generator has a field fuse which is intact; whereas a burned generator field fuse plus failure of the starter is a fair indication that there is a broken connection at points *1*, *2*, *3*, or *4*. If the generator produces current as indicated on the ammeter the field fuse is intact.

1253. Parenthetically, it must be explained that these thumb rules are not intended to find every case of electrical trouble but they will find 99 out of 100; the hundredth trouble may be left for the expert. This paragraph also applies rather generally to all trouble finding directions in this book.

1254. Cure—5. If cures 1, 2, 3, or 4 fail, the trouble is probably within the starting motor, and it should be examined and repaired by an experienced man.

ONE LAMP TOO BRIGHT

1255. Symptom—One lamp too bright.

1256. Causes—(1) Candlepower of bulb too high. (2) Voltage of bulb too low.

1257. Cure—1. Examine bulb. Remember that a bulb requires 1 watt per candlepower; therefore if it is marked 21 watts it is designed to give 21 candlepower. The maximum candlepower in general use is 21, therefore it is not likely that a head-lamp bulb will be too bright from this cause, and a 21-candlepower bulb is not likely to fit in a tail-lamp. If a 21-candlepower bulb is put into a side lamp where a 4-candlepower bulb is ordinarily used, the light will be too bright.

1258. Cure—2. If a 6-volt bulb is used in a 12-volt system or a 3-volt bulb in a 6-volt system it will be much brighter than normal, and its life will be correspondingly short. Examine the bulb to determine whether its voltage is correct. Six-volt bulbs are usually rated 6 to 8 volts and 12-volt bulbs 12 to 16 volts. Occasionally, two 3-volt bulbs are used in series on a 6-volt circuit, or two 6-volt bulbs are placed in series on a 12-volt circuit. Instrument-board and tail-lamps are sometimes connected in the way; so are Ford headlights when the magneto is used for lighting—two 9-volt bulbs in series.

1259. When two bulbs are arranged in series a ground in the wire connecting them will cause one light to be bright and the other dim, or a short-circuit across either bulb will dim this bulb while the other becomes proportionately brighter.

ONE LAMP DIM

1260. Symptom—One lamp dim.

1261. Causes—(1) Candlepower of bulb too low. (2) Voltage of bulb too high. (3) Loose or dirty connection anywhere in wiring individual to this lamp. (4) Dirty lens glass or reflector.

1262. Cure—1. Examine bulb and replace it with bulb of correct candlepower.

1263. Cure—2. Examine bulb and replace it with bulb of correct voltage.

1264. Cure—3. A frequent cause of a dim lamp is a poor ground connection anywhere between the lamp socket and the car frame. This is pa ticularly true of cars that are old enough to have accumulated considerable rust. The easiest way to check this point is to obtain a piece of insulated copper wire about 5 feet long. Touch one end to the lamp bulb socket and the other end to some brightly polished metal spot on frame or engine. If the lamp glows brightly it indicates a poor ground connection. For accuracy in making this test it is rather essential to provide the test wire with spring terminal clips. Be sure to attach the wire to the lamp socket and not to the terminal in the socket. Any loose bolts in the lamp brackets should be tightened, and if the lamp is mounted on a fender, the fender bolts should also be examined for tightness. If the fenders have been recently painted, paint between the fender and the car frame may be causing the trouble, in which case remove one fender bolt, remove all paint from it and sandpaper both frame and fender bracket where they contact with the bolt head and nut.

1265. If contact between the lamp housing and the reflector is poor due to rust or corrosion, clean these parts with fine sandpaper. A better plan is to connect the two parts with a piece of stranded copper wire about 12 inches long, soldering it in place. One end is soldered to the back of the reflector and the other to the front of the lamp housing.

1266. A slightly loose or dirty connection at any other point in the circuit may also cause a dim bulb. Inasmuch as the assumption is that only one lamp is dim, the trouble must be in the circuit individual to this lamp. In the case of the tail-lamp (Figure 80), this means that there may be a loose connection anywhere between the bulb and point 18. If two lamps are partly served by a common wire, as the head or sidelamps (Figure 80), the wire common to the two lamps may be eliminated from consideration, and therefore a single dim head or side lamp must be due to a loose or dirty connection at or within the lamp, or in the wire individual to this lamp.

1267. Press in on the lamp bulb. If it becomes bright the dimness is due to loose or dirty contact in the lamp socket. Turn off the lighting switch, remove the lamp and pull out gently on the socket pin to increase the tension in its spring. If the trouble remains, put a small drop of solder on the point on the base of the lamp bulb; if this is not sufficient, put in new socket parts.

1267A. If there is a socket connection outside the lamp housing (Figure 84), test this point similarly. Clean and tighten all connections within the lamp housing. If a lamp has individual wiring, such as the tail-lamp, tighten screw at point *18* (Figure 80), cleaning connection with fine sandpaper if it is dirty. If there is a fuse, *AB*, remove it and clean the ends of the fuse as well as its clips with fine sandpaper. Press spring clips together slightly to increase tension before replacing fuse. Clean and tighten fuse terminal connections.

1268. Cure—4. Clean lens glass and reflector.

ONE LAMP FLICKERS

1269. Symptom—One lamp flickers.

1270. Cause—1. Intermittent loose connection in the circuit individual to this lamp.

1271. Cure—1. Same as for dim lamp, paragraph 1264. The cause of flickering may often be determined by pressure on suspected parts. In the case of a lamp mounted on a fender, pulling up or down on the fender may produce flickering, and the same for all other parts in the circuit subject to vibration, including the lamp bulb, and all metal parts and wires within the lamp housing, as well as all external wires in this individual circuit. Test all connections by alternately pulling and pushing them gently.

1272. If the circuit is not protected by either a main or individual fuse, or by vibrating or lockout circuit breakers, or if the fuse has been replaced by a piece of copper, the flickering may possibly be due to a ground somewhere in this circuit, the ammeter showing a much higher discharge rate with the lamp dim or dead than with it bright. If the ground is not discovered by a careful examination of the insulation on the wires in this circuit, have an expert look for the trouble, or put in new wiring—the latter is often quicker. All defective insulation should be taped or new wires put in if the insulation is badly rotted. Note that fuses are protective devices and that burned wiring or more serious troubles may result from replacing them with copper.

ONE LAMP DEAD

1273. Symptom—One lamp dead.

1274. Causes—(1) Bulb burned out. (2) Fuse blown or wire burned out. (3) Dirty, loose, or open connection including wrongly connected or broken wire.

1275. Cure—1. Bulbs burn out due to old age, although this may be hastened by excessive vibration, as when a lamp is mounted on a loose fender, or because a bulb is of lower voltage than required. Put in a new bulb of the correct voltage.

1276. Cure—2. Examine individual fuse, if there is one on this circuit. If it is blown, examine all wiring between fuse and bulb for defective insulation which allows the bare wire to come into contact with some metal part. Also, if the wires are not provided with terminal lugs but the strands are merely wrapped around the terminal, look for stray strands causing a ground. Do not replace fuse until trouble is found.

1277. Rarely it may be found that any wire in circuit not protected by a fuse, but exposed to a heavy ground current may have its insulation burned off, or the wire may be melted in two. Look for charred insulation on all wires individual to this circuit. This condition will be preceded by blue smoke and the smell of burning rubber, therefore it is not an easy trouble to miss. A burned wire usually indicates a heavy ground in this wire, although sometimes the ground may be between this wire and the lamp bulb.

1278. In any case, look for the ground, taping insulation or putting in new wiring as required. If you are unable to find the ground, go to an experienced man.

1279. Cure—3. In some troubles the slightest looseness or dirt or both at any point in the circuit will prevent the lamp from lighting. Inspect all wiring individual to this circuit, which in the case of the tail-lamp, means all wiring and connections between the bulb and point *18* (Figure 80). Proceed to find the trouble as described under One Lamp Dim, paragraph 1264.

1280. As an illustration of how slight a defect may cause a dead lamp, it is worth stating that the mere removal and replacement of a fuse has resulted in a dead lamp. The contact between fuse and clips being sufficiently good before removal to allow the lamp to light, and not good enough after replacement, to permit it to light, in spite of the fact that the fuse was correctly replaced. Subsequent removal and replacement resulted in the lamp lighting. The ends of the fuse and its clips were not noticeably corroded, and the contact between fuse and clips was apparently good. The explanation of this case lies in the fact while corrosion was hardly apparent, nevertheless it was sufficient when the fuse was first replaced to prevent the lighting of the bulb, the condition being aided by fuse clips just a trifle too loose. The remedy in this case is to scrape or sandpaper fuse clips and fuse ends to a bright surface and bend the clips together slightly to increase their tension.

TWO LAMPS TOO BRIGHT

1281. Symptom—Two lamps too bright.

1282. Note: The symptom refers to any two lamps connected to the same switch point, as two headlights or two side lights. Two bright lamps are not likely to be noticed because a basis of comparison is lacking. Two lamps may be bright for any of the reasons noted under One Lamp too Bright, paragraph 1255.

TWO LAMPS DIM

1283. Symptom—Two lamps dim.

1284. Causes—(1) Candlepower of bulbs too low or voltage of bulbs too high for battery voltage. (2) Dirty or loose connection. (3) Other defects.

1285. Cure—1. See paragraph 1261.

1286. Cure—2. Consider the headlight circuit (Figure 80). Examine point *20* for dirty or loose connections, and if there is an individual fuse, examine fuse, clips, and fuse terminals.

1287. If the trouble is not found, treat both lamps as described for One Lamp Dim, paragraph 1264.

1288. If the trouble is still undetermined, it may be due to a poor connection at point *21*, or to a poor switch contact. If the former is difficult to reach, see paragraph 1302. If by process of elimination, a poor switch contact is indicated, the switch may be disassambled, and repairs made as required, although most readers will find it more satisfactory to have switch repairs made by an experienced man.

1289. Cure—3. Do not assume that only two lamps are dim before looking to make sure that all lamps are not dim. If all lamps are dim, see paragraph 1310. See that lens glasses and reflectors are clean and bright.

TWO LAMPS FLICKER

1290. Symptom—Two lamps flicker.

1291. Causes—(1) Loose connection. (2) Ground. (3) Other defects.

1292. Note: The ammeter will read below normal if the cause is a loose connection, and above normal if the cause is a ground. Normal reading is explained in paragraph 1232.

1293. Cure—1. Consider the headlight circuit (Figure 80). If flickering is common to both lamps it is probable that the trouble lies in the circuit common to both lamps, as between points *20* and *21*. Flickering occurs because vibration permits the contact to be alternately good and bad. Examine, clean, and tighten points *20* and *21*, omitting the latter if it is difficult to reach until all other points have been examined. If the circuit is provided with an individual fuse, examine, clean and tighten fuse clips and fuse terminals.

1294. If the lamps do not flicker in unison, treat each lamp separately as described under One Lamp Flickers, paragraph 1269.

1295. Cure—2. If the circuit is protected either by a main or individual fuse, a ground sufficient to cause flickering is likely to blow the fuse and cause dead lamps, which is not the case under consideration. But if the circuit is not protected by a fuse or if the fuse has been replaced by a piece of copper wire or tube, an intermittent ground anywhere in the circuit may cause flickering of all lamps in circuit. This means that if the tail-light is on with the two headlights, the three lamps will flicker in unison. To determine whether the ground is in the tail-lamp circuit or in the head-lamp circuit, switch on the sidelamps. If the latter two flicker in unison with the tail-lamp it shows that the ground is in the tail-lamp circuit. On the other hand, if flickering stops, the ground is in the head-lamp circuit.

1296. When the circuit with the ground is thus found, examine all wiring for grounds, taping wiring or replacing it as required. If the trouble is still uncured, replace the defective wiring or have an experienced man go over these circuits.

1297. Cure—3. Do not mistake Two Lamps Flickering for All Lamps Flickering, paragraph 1318.

TWO LAMPS DEAD

1298. Symptom—Two lamps dead.

1299. Causes—(1) Both bulbs burned out. (2) Fuse blown or wire burned out. (3) Dirty, loose or broken connection.

1300. Cure—1. Examine bulbs and replace if found defective.

1301. Cure—2. Consider the headlight circuit (Figure 80). If this circuit has an individual fuse, *AB*, examine it. If it is blown, look for a ground anywhere between *B* and either headlight bulb. Tape any worn insulation, or replace wires if insulation is badly rotted. When all apparent troubles have been repaired put in a new fuse. If it blows, have an experienced man go over the circuit.

1302. Headlight and side light wires are sometimes inclosed at points *21* and *20* respectively by a split tee fitting the halves of which are held together by screws. After the car has seen some service the chafing of the wires within may result in a ground. In this case the ground will be removed, if the top half of the fitting is removed, and the wires lifted out of contact with the bottom half of the fitting. The remedy is to tape any exposed wiring at points *21* or *20*. It should be understood that points *21* and *20* are invariably found inside of the same fitting.

1303. If there is no individual fuse nor a main fuse, look for a burned wire anywhere between either bulb and point *20*. Replace this wire, and examine all wires beyond this one for a ground. Burned switch points or ammeter are also possibilities, the latter being indicated by fogging of the glass or failure to work. If there is an individual fuse and it is intact, look for a burned wire between point *20* and *A*.

1304. Cure—3. A loose or dirty connection to affect both lamps must occur between points *20* and *21*, unless the switch points are defective. Examine, clean, and tighten point *20*, and fuse clips and terminals if the circuit has an individual fuse. There is also a slight possibility that point *21* is loose or dirty.

1305. In rare instances two dead lamps may be due to faulty ground connections at each lamp. See paragraph 1264, under One Lamp Dim.

THREE LAMPS

1306. See All Lamps.

ALL LAMPS TOO BRIGHT

1307. Symptom—All lamps too bright.

1308. Causes—(1) Loose or dirty connection in battery-generator circuit. (2) Causes mentioned under one lamp are extremely unlikely for all lamps; nevertheless they should be kept in mind. See One Lamp Too Bright. paragraph 1255.

1309. Cure—1. Brightness beyond that produced by a fully charged battery is unlikely on cars equipped with a generator field fuse. However, if excessive brightness is noted when the generator is charging it indicates a loose or dirty connection at points *1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13* (Figure 80). Points *1, 2, 3,* are most likely to be dirty but all should be examined for looseness. Carefully remove the cover from the cutout and pass a fine file between the points to clean them if they appear dirty. Be sure to put the cutout cover back.

ALL LAMPS DIM

1310. Symptom—All lamps dim.

1311. Causes—(1) Battery discharged. (2) Generator defective. (3) Loose or dirty connections at points *1, 2, 3, 4, 7, 8, 15, 16* (Figure 80).

1312. Cure—1. See paragraph 1135 regarding battery, but also note that the trouble may be due to loose connections mentioned in Cause 3, although in most cases it is the battery that is at fault. If lights are dim when supplied by battery but a trifle brighter when generator is charging it is a fair indication that battery is at fault. Dim lights on battery and excessively bright lights with generator charging indicate a dirty or loose connection at points *1, 2, 3, 4, 7, 9, 10, 11, 12, 13.*

1313. If the lights are so dim that they barely glow, it is probable that the battery is completely run down, although there is a slight possibility that there is a loose or dirty connection at one of the points mentioned in Cause 3. With dull red lamps, not enough current will be supplied to the ignition to permit starting the engine by hand.

1314. Cure—2. If you know the normal charging rate of your generator at say, 25 miles an hour on high gear, drive the car at this speed and note whether the ammeter gives its usual reading, say 12 amperes. If less than the normal figure, the generator is at fault. If the generator has been run more than 10.000 miles without attention, its commutator probably needs to be trued in a lathe, and then new brushes should be installed. In any case, work on the generator should be done by an experienced man, an electrical expert, if possible, otherwise by your repairman.

1315. If the charging rate is normal according to your memory, it may still be too low as might be the case if the generator were adjusted to give a low charging rate for summer, and the rate was not changed when cold weather arrived. It only takes a moment to make this adjustment, but an experienced man should do it.

1316. If you are unable to say whether the charging rate is normal, or if your car is not equipped with an ammeter, note whether the lights become brighter when the generator is charging. If not, the generator probably requires repairing.

1317. Cure—3. If the previous tests indicate that battery and generator are all right, examine all points mentioned in Cause 3 for dirt and looseness; clean and tighten as required.

ALL LAMPS FLICKER

1318. Symptom—All Lamps Flicker.

1319. Note: This head also includes three or more lamps.

1320. Causes—(1) Loose connection. (2) Ground.

1321. Cure—1. Flickering may be caused by a loose connection at points *1, 2, 3, 4, 7, 8, 15;* and *16* if there is a main fuse (Figure 80). Inspect these points and tighten any that are loose.

1322. Cure—2. Flickering of all or nearly all lights may be caused by an intermittent ground at or between points *3, 4, 7, 8, 9, 15.* If flickering occurs with ignition on, but not with it off, there is an intermittent ground at or between points *29, 30.* With ignition and lighting switches off and car coasting to provide vibration, fluctuation of ammeter hand between zero and discharge usually indicates ground at or between points *8, 9, 15.*

1323. If with generator charging and lights off, ammeter hand fluctuates between normal charge and some point above, a ground at or between points *3, 4, 7* is indicated.

1324. If no fluctuation of the ammeter hand is noted as described in the two previous paragraphs, turn on headlamps, then side lamps. If flickering is noted in both cases, ground is probably in tail-light circuit. If flickering is only noted with headlamps on, ground is in head-lamp circuit; and same for side-lamp circuit.

1325. Flickering due to a ground is likely to blow the main fuse if there is one, thus changing the symptom to All Lamps Dead, or blow the individual fuse if there is one, if the ground is between the fuse and the lamp or lamps, changing the symptom to One or Two Lamps Dead.

1326. If your car is equipped with a Delco switch with a vibrating circuit breaker, rapid flickering of the lights controlled by it may be noted if a ground occurs anywhere between circuit breaker and lights. A buzzing sound will also be heard. This circuit breaker usually controls the major lights. In some cases the minor lights such as interior lights, horn, cigar lighter, etc., are controlled by a lockout circuit breaker.

1327. Once the ground is approximately detected, all wiring in the circuits indicated should be inspected and any defective insulation taped or the wire replaced.

ALL LAMPS DEAD

1328. Symptom—All Lamps Dead.

1329. Causes—(1) Battery completely run down. (2) Loose, dirty, open connection, or ground. (3) Lamps burned out because of excessive voltage.

1330. Cure—1. A completely discharged battery is the most frequent cause of dead lights, usually preceded by dim lights, slow cranking, etc., unless complete discharge is due to leaving the ignition switch or lights on for several hours or days. See paragraph 1135, regarding battery troubles.

1331. Cure—2. All lamps dead may be due to a loose, dirty, or open connection at points *1, 2, 3, 4, 7, 8, 15;* and *16* if there is a main fuse (Figure 80). If starter works, points *1, 2, 3, 4* may be eliminated.

1332. If there is a main fuse, examine it first. If it is blown, look for a ground anywhere in the lighting circuit, examining the insulation of all wiring and taping any spots where insulation is chafed through.

1333. If there is no main fuse, look for a burned wire between points *4, 7, 8, 15;* this includes the ammeter. Note that the ground may have occurred in the burned wire or in any wire further along in the circuit, toward the lamp bulbs. The ammeter is probably ruined and the switch points may be damaged.

1334. If wires between points *4* and *15* are intact, and the main fuse, if there is one, is not blown, examine points *1* to *16* for loose, dirty, or open connections. If the starter does not work the trouble must be due to a dirty, loose, or open connection at points *1, 2, 3, 4;* otherwise these points may be eliminated. Examine points *2* and *3* with especial care. The slightest looseness at any of these points may prevent starter and lights from working.

1335. If starter works, examine points *4, 7, 8, 15, 16,* and be sure that the main fuse clips are tight. Tighten all loose connections, and scrape or sandpaper all dirty connections.

1336. Cure—3. Rarely, all lamps may be burned out due to excessive generated voltage caused by a loose, dirty, or open connection at or between points *1, 2, 3, 4, 5, 7, 8.* The lamps, of course, can burn out only if turned on when the voltage is excessive. Examine lamps to see if they are burned out. Points *1, 2, 3, 4* may be eliminated if the starter works. If the generator is protected by a field fuse (of correct capacity, usually 5 amperes) the field fuse will blow as a rule before the lamps are damaged, but main or individual fuses in the lighting circuit are not likely to blow when the voltage is excessive.

AMMETER TROUBLES

1337. Note: If the car is equipped with an indicator reading, Charge, Discharge, and Off, it should be treated the same as an ammeter throughout the discussion of ammeter troubles.

AMMETER HAND STICKS

1338. Symptom—Ammeter hand sticks.

1339. Cause—A defect within ammeter.

1340. Cure—Tap ammeter sharply with fingers. If trouble persists, put in new ammeter.

AMMETER DOES NOT CHARGE

1341. Note: Continued operation of car when ammeter fails to show charge will blow field fuse of generator. Therefore if trouble is not cured, remove field fuse. If generator has no field fuse, the generator is likely to be ruined if car is run more than a short distance. For remedy see paragraph 1146. Otherwise run car not more than 15 miles per hour on high until repair is effected.

1342. Symptom—Ammeter fails to show charge.

1343. Causes—(1) Open connection. (2) Generator defective.

1344. Cure—1. With engine running approximately the equivalent of 15 miles an hour on high gear, carefully remove cutout cover. If cutout points (Figure 80), are closed, there must be an open connection at points *8* or *9*, or ammeter must be defective, unless lights are dead, in which case there is an open connection at points *8*, *7*, *1*, although the engine is not likely to run with an open connection at these points. If cutout points are separated, close them with the fingers. If points refuse to remain closed, stop engine and close points for about 5 seconds. Start engine. If cutout then fails to close, look for burned out generator field fuse. If field fuse is burned out, look for loose or open connection at points *1, 2, 3, 4, 7, 8, 9, 10; 11, 12, 13.* If found, tighten and replace field fuse. If not found, trouble is in cutout or generator and further work should be done by an experienced man. If starter is normal, points *1, 2, 3, 4* may be eliminated. If lights are normal the loose connection is most likely at point *13*, or at point *9* if cutout is mounted on the generator; thus points *1, 2, 3, 4, 7, 8*, may be eliminated.

1345. If generator is not provided with a cutout, look for open circuit between generator and ammeter if lights are normal and between ammeter and battery if lights are out. On Delco motor-generators see that all connections between motor-generator and switch are clean and tight.

1346. Cure—2. If the trouble is still undetected, it is probably in the generator. Take your car to an experienced man.

AMMETER READS DISCHARGE

1347. Symptom—Ammeter reads discharge with all switches off.

1348. Causes—(1) Ammeter defective. (2) Slight ground.

1349. Cure—1. This is rather unlikely, but only remedy is new ammeter. To test, disconnect wire at point *7* of Figure 80. If reading is unchanged, ammeter is probably defective.

1350. Cure—2. Disconnect wire at point *7*. If ammeter hand comes to zero, there is a ground at or between points *8*, *15*, *16*, *17*, *9*, or cutout points are stuck closed. Examine wires between these points for grounds, taping any defective insulation. If cutout points are stuck closed, clean with fine file slipped between the points. If this does not remedy the trouble take your car to an experienced man.

AMMETER FLUCTUATES

1351. Symptom—Ammeter hand fluctuates toward zero from a normal discharge reading with lights on.

1352. Cause—Loose connection. Cure—Examine points *8, 15, 16, 17* if all lamps flicker. If only one or two lamps flicker the loose connection is in the circuit affected.

1353. Symptom—Ammeter hand fluctuates between a normal discharge reading and a higher reading.

1354. Cause—Intermittent ground.

1355. Cure—If fluctuation disappears with all switches off, ground is in individual lighting circuit. If fluctuation continues, ground is in wire *8-9*, *8-15*, or cutout is vibrating. If the latter, take your car to an experienced man.

AMMETER READS HIGH ON CHARGE

1356. Symptom—Ammeter shows greater than normal charging rate, intermittently or continuously.

1357. Cause—Ground, intermittent or continuous, at or between points *3, 4, 7,* or loose connection (see paragraph 1309), or third-brush needs adjusting by an experienced man.

1358. Cure—Examine these wires, taping any defective insulation.

AMMETER REVERSED

1359. Symptom—Ammeter readings reversed.

1360. Cause—Connections reversed at ammeter.

1361. Cure—Reverse connections at ammeter, if ammeter reads charge when it should read discharge, and discharge when it should read charge

AMMETER GLASS FOGGED

1362. Symptom—Ammeter glass fogged.

1363. Causes—(1) Moisture. (2) Burning of insulation within ammeter.

1364. Cure—1. Abnormal atmospheric conditions may cause moisture to collect on the under side of the ammeter glass. Its presence may be ignored except that it must not be confused with cause 2.

1365. Cause—2. If the ammeter hand shows maximum discharge *plus*, it indicates that the burning is due to an extremely heavy current, due to a ground between point *8* and *15* if lights are off, or *8* and *9* if generator is not charging, or to a ground between points *8* and bulbs if there are no fuses or if fuses have been replaced by copper. If ignition switch is closed, the ground may be at or between points *29-30*. Look for ground in the circuit indicated.

1366. If the ammeter hand shows maximum charge *plus*, look for ground in wires *3-4* or *4-7*.

1367. If the ammeter hand reads less than normal on charge or discharge, the winding within the ammeter is probably short-circuited. A new ammeter should be put in, but until this can be done, remove wires from points *7* and *8* and connect them together, taping them carefully.

ELECTRIC HORNS

1368. Nearly all so-called electric horns produce their noise by the vibration of a metal diaphragm, the tone of the horn increasing in pitch as the rate of vibration increases. Two methods are used to cause the diaphragm to vibrate: The diaphragm is made of iron and is acted upon by an electro-magnet; the principle is the same as used on the vibrator of the Ford coil; a toothed cam is placed in contact with the diaphragm and is driven by a small electric motor. The former type of horn is called a vibrator horn, and two designs are shown in Figure 94. The latter is called a motor-driven horn (Figure 95. One of the vibrator horns shown has the electro-magnet acting directly on the diaphragm, whereas in the other the electro-magnet acts on an armature and plunger which strikes the diaphragm. In either type the points of the vibrator must be true and in proper adjustment, just as in the case of the Ford vibrator coil.

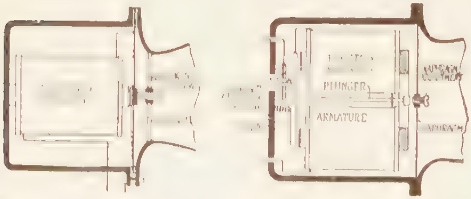


Figure 94.—Two vibrator horns: Left electro magnet acts direct on the diaphragm; right armature is used

1369. The motor-driven horn has a small electric motor with all the usual parts such as armature, field windings, commutator, and brushes. The motor bearings should be supplied with a few drops of oil about once a month. If the horn fails to blow, or is weak, the trouble may be a weak battery or a dirty or loose connection or ground. The method of detecting the trouble in this circuit is the same as that employed for One Lamp.

1370. About once a year the commutator should be wiped clean with a dry cloth and then lubricated with a few drops of light machine oil or thinly coated with vaseline. As in the case of starting motors, a badly worn commutator should be trued in a lathe, and badly worn brushes should be replaced with new ones. The tone of the vibrator horn depends on the vibrator adjustment and it may be varied within certain limits. The tone of the motor-driven horn depends on the speed of the motor and this in turn depends on how hard the cam strikes the diaphragm. The harder it strikes the greater the load on the motor, therefore the more slowly it rotates. At the same time the harder the cam hits the diaphragm the more powerful the sound. It is obvious, therefore, that there is a happy medium where power and tone are both satisfactory. This point may be obtained by adjusting the cam The tone of the horn should never be adjusted except when it is known that every part of the circuit including horn and battery are in prime condition. If the adjustment is much too loose the horn may fail to blow while the armature spins idly.

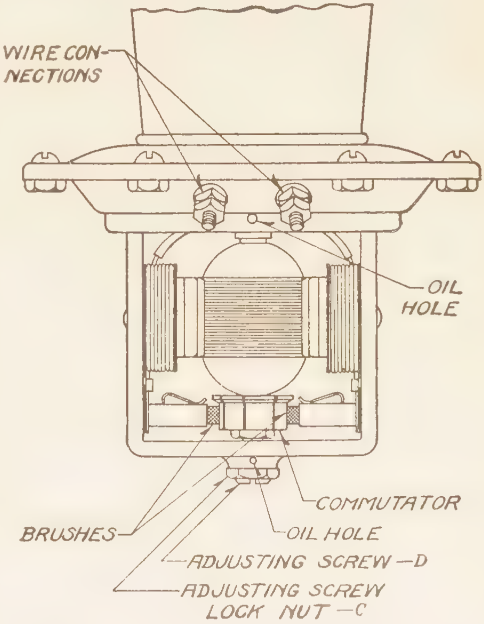


Figure 95.—Construction of a motor-driven horn

1371. Electrically operated windshield wipers employ either a small electric motor similar to that used in motor-driven horns or a magnetic mechanism.

CHAPTER XIII

ENGINE TROUBLES

ENGINE MISSES

1401. Note: For Ford Model T ignition troubles, see paragraph 1712.

1402. Symptom—The failure of one or more cylinders to fire, either occasionally or continuously is defined as missing.

1403. Form the habit of listening subconsciously to the exhaust whenever the engine is running.

1404. If the engine misses a single "beat" regularly, the miss is confined to one cylinder. If the missing is irregular, apparently skipping around from one cylinder to another, the cause is probably general to the engine, although it may be confined to two or three cylinders.

1405. Missing is accompanied by a jerky rotation of the engine and loss of power, both increasing with the amount of missing. If the engine is well mufiled, especially if it has more than six cylinders, the irregular running and loss of power may be the first symptoms noted. The note of the exhaust may be heard most clearly with throttle wide open, preferably running up grade or, allow the engine to run idly at a speed equivalent to 20 miles an hour and listen to the exhaust, standing at the rear of the car. If the car is equipped with a muffler cutout, open it, and the exhaust note may be heard clearly.

1406. Missing is somewhat harmful to the car in that the irregular running of the engine imposes an extra strain on all rotating parts from engine to rear tires. The damage may be minimized, however, by not allowing the engine to run too slowly; in other words, change to a lower gear when any tendency to "buck" is noted. If the missing is due to an exhaust valve which is not seating properly, the valve may be so badly burned that it must be replaced; if missing is caused by overheating or lack of oil, the engine may be damaged if the miss is ignored.

HOW TO FIND THE MISS

1407. The missing cylinder or cylinders may be found by one of the following methods:

1408. Method A With the engine warm, touch the various spark-plug shells with the fingers. If one cylinder has been missing consistently, its spark-plug shell will be considerably cooler than the others. If a moistened finger tip be touched to a spark-plug shell in a cylinder that is firing, sizzling may be noted, while the spark-plug on the missing cylinder will not produce sizzling. This test may be made either with the engine running or just shut off. Remember that a disagreeable shock will be experienced if you touch a spark-plug terminal while the engine is running.

1409. Method B—If the engine is provided with compression cups, these may be opened one by one while the engine is running above idling speed. If no flame is observed the cylinder is missing. If the cup is so constructed or so placed that the flame can not be seen, the volume of sound issuing from the cup may be taken as a guide, the missing cylinder being much weaker than the others. Similarly, the force of the explosion may be felt by placing the thumb about half an inch away from the open cup. Compression cups sometimes become clogged with carbon; then the tests described may be impossible until the cups are cleaned.

1410. Method C—Short-circuit the spark-plug terminals one by one with a screwdriver provided with a wooden handle. An unpleasant shock will be received if there is any metal in the handle. With the engine running, allow the shank of the screwdriver to touch the spark-plug terminal, while the tip of the screwdriver rests on the cylinder casting. When a plug is thus short-circuited, missing is produced in this cylinder. Therefore it is plain that when the plug in the missing cylinder is short-circuited no difference will be heard in the exhaust note and no drop in engine speed will be noted, whereas when the spark-plug in a good cylinder is short-circuited, another miss will be noted in the exhaust and the engine speed will drop, due to the cutting out of this cylinder.

1411. Method A is the easiest to use but is not of much service if one or more cylinders miss occasionally instead of continuously. Methods B and C may be used to detect a cylinder which fires some of the time and misses some of the time.

1412. Cures—If any one of the foregoing tests indicate that the miss is definitely confined to one or more cylinders, proceed as described in paragraph 1414. But if these tests indicate that the miss is more or less general to all cylinders, see paragraph 1436.

ONE CYLINDER MISSES

1413. Cause—Ordinarily, missing is due to failure of a hot spark to jump between the points of the plug, and this in turn may be due to:

(a) Spark-plug points too far apart.
(b) Spark-plug points too close together.
(c) Porcelain insulator cracked.
(d) Porcelain insulator porous.

(e) Porcelain insulator fouled with oil, carbon, or rarely moisture.
(f) Bridging of the gap between the points by oil, carbon, or moisture.
(g) Disconnection of high-tension wire running to this cylinder, either at the spark plug terminal or at the other end.
(h) Grounding of this wire.
(i) Water or dirt on the outside of the spark-plug porcelain.
(j) High-tension wire connected to wrong spark-plug.
(k) Faulty insulation on wire to this spark-plug.

1414. Cure—After detecting the missing cylinder, be sure that the high-tension wire is not disconnected at the plug. Then run the fingers over this wire as far as possible, to determine that the wire has not come in contact with any metal part, allowing the insulation to chafe through, grounding the high-tension current before it reaches the spark-plug. If such a spot is found, tape it carefully. If the exposed surface of the spark-plug porcelain is wet or dirty wipe it off. After remedying any of these defects test the engine to see if the miss has disappeared.

1415. If no external defects are found, remove the spark-plug. If the interior of the plug is moist with oil it confirms the suspicion that this cylinder has been missing. But if the interior is dry, the cylinder is probably all right, in which case an error in diagnosis has been made, or the cylinder has been firing part of the time.

MISSING CAUSED BY SPARK-PLUG

1416. Remove the spark-plug and examine it carefully as to the following points:

(a) Spark-plug points should be approximately $\frac{1}{32}$ inch apart.
(b) Porcelain should be clean.
(c) Porcelain should not be cracked.

A—Adjust the spark-plug points as required by bending them gently with a pliers. If the points are badly burned, as may be the case after 20,000 miles or more, put in a new plug.

B—Scrape all carbon from the porcelain, using a small screwdriver or other convenient tool, but be careful not to scratch porcelain; and then polish porcelain with a rag if possible.

C—Examine the plug carefully to see that the porcelain is not cracked or broken. Any fracture of the porcelain is likely to cause missing, in which case a new plug should be inserted and the old one discarded.

1417. If the plug is made in two pieces, the work on it may often be facilitated by taking the plug apart by unscrewing the hexagonal nut surrounding the porcelain. Be careful in putting the plug together to put the copper-asbestos gaskets back where they belong, tighten the nut as far as it will go and then adjust the spark-plug points, as disassembly of the plug disturbs the adjustment.

1418. After repairing the plug as described or procuring a new one, put it into the cylinder, first being certain that the copper-asbestos gasket between plug and cylinder is in place, connect the high-tension wire to it and *test* the engine. In about 99 troubles of 100 the miss will have disappeared, because the majority of misses are due to carbon deposit on spark-plug porcelain or to need for adjustment of the spark-plug points. *Note:* A gasket between spark-plug and cylinder is not required if the spark-plug has a pipe thread (tapered).

1419. If the missing continues, and you are at all doubtful as to the plug put back, remove it and put in a new one, or at least an old one of known quality.

1420. If the miss is cured temporarily but returns shortly it will probably be found that this cylinder is receiving too much oil (see paragraph 670), although it must also be remembered that if the spark-plug is too long for the engine in question, oil-fouling may result. The motor-car manufacturer's recommendation should be accepted regarding type of spark-plug. If this information is not available good results will usually be obtained if the spark-plug points come about flush with the walls of the combustion chamber.

CONTINUED MISSING

1421. It is possible that moisture has affected the high-tension wire leading to this spark-plug more than the others, in which case the missing will disappear after the engine has become thoroughly warm, unless it is exposed to more moisture. (See paragraph 1509.)

1422. If the missing continues, there is a slight possibility that the distributor cap has become cracked or it is covered with moisture or dirt inside or out. Remove the cap, clean it and examine it minutely for cracks; a hair crack may cause the trouble. A cracked cap must be replaced. Make sure that the connection of the high-tension wire at the distributor is secure. Also examine rotor for crack, and discard if found. For temporary repair, cut dirt out of cracks, and fill with paraffin or shellac.

1423. If the missing continues, it is most probably due to excessive cylinder leakage through valve leakage, although leakage past the piston must not be overlooked. (See paragraph 670.) Leakage past an intake valve is invariably accompanied by backfiring.

VALVE LEAKAGE

1424. Cause—A valve may leak because it is too tightly adjusted, because it needs grinding, because the spring is broken or the spring seat retaining pin is broken or missing, because it sticks open due to the valve stem being too tight a fit in its guide, due to carbon deposit on the stem, or to warping of the stem. Warping of the head will also produce leakage.

1425. Cure—Examine the clearance between valve stem and push rod on intake and exhaust valves on the missing cylinder. For details see paragraph 638.

1426. If there is no clearance on the intake valve, the missing must be accompanied by backfiring. Lack of clearance may be caused by previous careless adjustment, or loosening of the adjusting nuts. Adjust the valve clearance if necessary.

1427. Excessive clearance, when it is known that the adjustment *was* correct, and provided that the adjusting nuts are still tight, indicates that the valve is sticking, or that there is carbon deposit on valve face and seat, and that the valve requires grinding. Occasionally, the excessive clearance may be due to shoulders on the valve face, warpage of the valve head, or carbon deposit on the valve stem. These occasional troubles will cause burning of the valve, necessitating its replacement if their cure is long postponed, although the cure is a shop job. (See paragraph 644.)

1428. Look carefully for a sticking valve. This is accompanied by a loud valve tapping, and in extreme cases by knocking due to extreme lameness of this cylinder. A sticking valve is usually indicated by 1/[illegible]-inch clearance or more between valve stem and push rod. Force the valve closed with any convenient tool such as a screwdriver. Squirt a mixture of kerosene and cylinder oil over the valve stem, using cylinder oil alone if kerosene is not available. This treatment will often cure a valve which is too tight a fit. (For further details see paragraph 644.)

1429. Similar trouble may be produced by a broken valve spring, broken or missing valve seat retaining pin, warped valve stem, sticking rocker arm on overhead valve engines. (See paragraph 648.)

TESTING COMPRESSION

1430. The compression may be tested as a check on conditions revealed by examination of the valves. (For details see paragraph 615.) If there is no compression in this cylinder, the missing is caused by valve leakage. If the missing disappears when the engine is run with throttle wide open, preferably under load, the exhaust valve probably requires grinding or adjusting. If the missing continues at high speed, the exhaust valve is probably stuck, not seating due to much too tight an adjustment, badly warped, or suffering from a weak or broken spring. (See paragraph 644.)

ONE CYLINDER MISSES AT HIGH SPEED ONLY

1431. If missing occurs only at high speed, the spark-plug points are probably too close together, although there is a small chance that the missing is caused by a weak valve spring.

ONE CYLINDER MISSES AT LOW SPEED ONLY

1432. Missing at low speed may be due to spark-plug points that are too close together, or to a leaky valve, or leaky intake valve stem guide. (See paragraph 650.)

MORE THAN ONE CYLINDER MISSES

1433. If more than one cylinder misses regularly and definitely, proceed as described in paragraph 1414, for treating one cylinder.

CAUSES OF GENERAL MISSING

1434. If the miss is not confined to any one cylinder but skips around, proceed as outlined in the following paragraphs:

1435. Causes:

(a) All spark-plugs partly fouled by oil, carbon accumulation, or excessively rich mixture.
(b) All spark-plugs need adjustment.
(c) Wet spark-plugs, high-tension wiring or distributor, or high-tension wiring has defective insulation.
(d) Dirty or oily distributor cap.
(e) Main high-tension wire intermittently grounded.
(f) Distributor brush trouble.
(g) Distributor cracked.
(h) Breaker requires truing or adjusting.
(i) Condenser defective.
(j) Loose, or dirty connection or ground in low-tension circuit.
(k) Battery run down.
(l) Dirt in carburetor.
(m) Incorrect mixture.
(n) All valves need adjusting.
(o) Engine overheated.

PROCEDURE

1436. See that choke is not on, and that mixture heating mechanism is in working order, especially in cold weather. If engine is wet, wipe moisture from outside of spark-plug porcelains, wipe distributor cap thoroughly inside and out. Missing caused by wet wires will often disappear when engine is warm.

1437. Examine high-tension wire running from coil to distributor cap and tape any points where insulation is worn or preferably replace it. Be sure wire is securely connected at both ends.

1438. Examine wire running from breaker mechanism to coil, tightening loose terminals and taping any worn spots on the insulation, or replace wire.

1439. Similarly, treat wire running from coil to ignition switch; wire running from ignition switch to ammeter; wire running from ammeter to starter switch (usually), cable running from starter switch to battery, cable running from battery to ground connection on car frame.

1440. If car is equipped with high-tension magneto, disconnect ignition switch wire at magneto. If missing disappears, look for worn insulation in this wire and tape any doubtful spot.

SPECIAL MISSING TROUBLES

1441. In seeking a general miss, the previous history of the car is helpful, as follows:

1442. If the valves have just been ground, general missing indicates valves too tightly adjusted or valves with shoulders on their faces, accompanied by hard starting, and backfiring if the trouble is found in intake valves. If the engine has overhead valves with a detachable head, tightening the head after the valves have been adjusted may produce missing and hard starting by wiping out the valve clearances.

1443. If the valves have just been adjusted, missing at low speed indicates too tight an adjustment.

1444. If spark plugs have just been adjusted, missing at high speed indicates points too close; missing at low speed, points too far apart.

1445. If cooling water is boiling, missing indicates an overheated engine. Missing will disappear when engine is cool.

1446. If carburetor has not been drained recently, occasional missing may be due to dirt in carburetor. Drain carburetor.

1447. If lubrication of rocker arms on overhead valve engine has been neglected, missing may indicate sticking rockers.

1448. If the breaker mechanism has not been adjusted in several thousand miles, missing may be due to need for truing and adjusting breaker points.

1449. If high-tension wiring, spark-plugs or distributor is wet, missing may occur, disappearing when the engine is warm.

1450. If high tension wiring has rotted insulation, missing may be caused by general leakage of current.

GENERAL MISSING—ALL SPEEDS

1451. Symptom—General missing at all speeds.

1452. Cure—If it is known that the missing is not due to one of the specific causes mentioned in paragraphs 1441 to 1450, proceed as follows:

1453. Look at the breaker mechanism first, bearing in mind that dirt between the points may cause missing. Dirt may be removed by passing a fine file between them. The breaker points should be smooth and true and should meet squarely, and when separated should have a gap of about $\frac{1}{64}$ inch. This gap varies slightly with different ignition systems and where the correct gap is not known, as determined by a feeler gage, adjust the breaker points to $\frac{1}{64}$ inch. If engine starts hard or refuses to start or if tendency to buck at slow speed is noted, points are probably too far apart. If points are too close together, an engine may miss at high speed, and if much too close together it may not run at all. (For further details see paragraph 1161.)

1454. Be careful to adjust the points when they are *fully* separated. With the spark half-way advanced, turn the engine over by hand until the points are separated, then bring the points to maximum separation by moving the spark lever one way or the other as required.

1455. Another method is to disconnect the spark-advance rod so that the distributor housing may be rotated by hand until the breaker points are fully separated. This method is excellent; but be sure to re-attach the spark-rod before cranking the engine or a back-kick may be experienced.

1456. Need for breaker-point adjustment is usually preceded by a period when the engine starts hard and bucks at low speed.

1457. If the breaker points burn away rapidly it suggests that the condenser is defective, or condenser connections are loose or grounded, or that there is dirt or oil between the breaker points. "Pirate" breaker points made of faulty material may also burn away rapidly.

1458. Examine distributor cap, and clean it if necessary. If distributor brush is badly worn so that it is making poor contact, it may be necessary to replace it; the same holds true of the distributor cap if it is badly worn. A distributor cap must be discarded if it is cracked.

1459. Proceed as described in paragraph 1436.

1460. Mixture much too rich or too lean. (See paragraph 916.) Also note that a defective vacuum tank may cause missing by delivering liquid fuel through vacuum pipe to intake manifold.

GENERAL MISSING AT HIGH SPEED

1461. Symptom—General missing at high speed only.

1462. Causes—(1) Breaker points too close together. (2) Spark-plug points too close together. (3) Mixture incorrect at high speed. (4) Weak valve springs. (5) Wrong spark-plugs.

1463. Cure—(1) Increase the distance between breaker points. (2) Spread spark-plug points until gap is $\frac{1}{32}$ inch. (3) Adjust carburetor. (See paragraph 913.) (4) Put in new valve springs. (See paragraph 652.) (5) Use exact make and type of plugs recommended by the car manufacturer. If missing (or backfiring) results from very fast driving use "cooler" plugs of the same make.

GENERAL MISSING AT LOW SPEED

1464. Symptom—General missing at low speed only.

1465. Causes—(1) Spark-plug points too far apart. (2) Breaker points too far apart. (3) Mixture incorrect at low speed. (4) Heating apparatus not functioning. (5) Choke pulled out. (6) Leaky valves. (7) Leaky intake valve guides. (8) Leaky intake pipe.

1466. Cure—(1) Adjust plug points to $\frac{1}{32}$ inch. (2) Adjust breaker points. (See paragraph 1161.) (3) Adjust mixture. (See paragraph 914.) (4) Examine piping to make sure that it is all intact and that any dampers and valves are set properly. (5) Push choke in. (6) See paragraph 615. (7) Valves with oversize stems required. (See paragraph 632.) (8) See paragraph 1639.

ENGINE STALLS

1467. Note: For Ford ignition troubles, see paragraph 1712.

1468. Symptom—Engine stalls.

1469. Cause—Failure of ignition, carburetion or valves. If the cylinders are served with a good mixture, if good sparks properly timed are provided, and if the valves function correctly the engine must run. These considerations are fundamental.

1470. If the engine stops, note the contributory symptoms:

(A) If it stops suddenly without warning just as though the ignition switch were shut off, look for ignition trouble.

(B) If permanent stalling is preceded by intermittent missing or stalling, as described under A, sometimes accompanied by muffler explosions, look for ignition trouble.

(C) If the engine "peters out" as though the throttle were suddenly closed all the way, look for carburetor trouble (usually dirt, or lack of oil if the Kingston Oil-Vac system is fitted).

(D) If petering out is preceded by loss of power, backfiring, or missing (without muffler explosions) the trouble is almost certainly due to dirt in the fuel system.

1471. The foregoing directions will often enable you to detect the trouble quickly, otherwise proceed as described below.

1472. Before proceeding with the trouble hunt, it is advisable for the general information of the reader to tabulate the causes of engine stoppage approximately arranged as to probability, as follows:

(a) Lack of gasoline.
(b) Ignition switch off.
(c) Dirt or water in fuel system.
(d) Carburetor out of adjustment.
(e) Failure of fuel feed system.
(f) Weak battery.
(g) Breaker mechanism needs adjusting.
(h) Loose, dirty, or open connection or ground in low-tension circuit.
(i) Ground in high-tension wire from coil to distributor.
(j) Dirty distributor, or broken or worn rotor brush.
(k) Wires, plugs or distributor wet, or defective high-tension insulation.
(l) Plugs fouled with oil.
(m) All valves adjusted too tight.
(n) Spark timing incorrect.
(o) Valve timing incorrect.
(p) Cracked distributor.
(q) Vacuum tank float stuck down.
(r) Clogged intake or exhaust or muffler.

HOW TO CURE STALLING

1473. The cause of the stalling may be determined as follows, although some steps below may be eliminated if symptoms A, B, C, D (paragraph 1470) have been noted:

1474. See that the ignition switch is on, all the way and that it has not been turned off by mistake.

1475. Flood carburetor, as described in paragraph 935.

1476. If carburetor can not be flooded, see if there is gasoline in the tank. If tank is empty or *nearly* empty you have found the trouble. See paragraph 908 regarding filling of vacuum tank. Symptoms C and D describe stalling due to lack of gasoline. If there is plenty of fuel in rear tank see paragraph 1480.

1477. If carburetor floods readily but engine refuses to start, the trouble is probably in the ignition system. To determine this point definitely, prime engine by pouring a teaspoonful of gasoline into each petcock, or pour a couple of tablespoonfuls of gasoline into the intake manifold, or into the intake opening of the carburetor (if the opening is on the top of the carburetor). If engine gives even a few explosions after priming it shows that ignition is correct. (See paragraph 1478.) But if no explosions are obtained the ignition system is at fault. (See paragraph 1491.) If the engine runs a few revolutions and stops, look for clogged exhaust pipe or muffler, noting how freely exhaust blows from muffler tail pipe.

FUEL SYSTEM FAULTS

1478. There is one exception, however: If the engine stalls due to too rich a mixture, priming will not produce any effect. If this difficulty is suspected, see that choke is not sticking closed. Open choke and throttle wide, and also open all petcocks, and crank engine through several revolutions with ignition switch on. A few explosions should be obtained as soon as the rich mixture is cleared out, and perhaps the engine will run continuously. If not, close petcocks, nearly close throttle and try to start engine in the usual way. If engine starts, trouble is due to too rich mixture. (See paragraph 915.) Too rich a mixture may be due to the float in vacuum tank sticking down. (See paragraph 908.)

1479. If carburetor-float valve can not be raised from its seat, shut off gasoline, remove float mechanism and examine all points carefully for defects.

1480. If carburetor can not be flooded, yet there is gasoline in the rear tank, turn off gasoline supply underneath vacuum tank and remove pipe from vacuum tank to carburetor. Blow through this pipe with the mouth, noting whether it is clogged with dirt. If so, blow it clear, run a wire through it, or if necessary use compressed air on it, although the hand air pump will do if a compressed air supply is not handy. If there is no shut-off cock, drain vacuum tank dry through carburetor.

1481. If this pipe is not clogged with dirt, turn on gasoline under vacuum tank and note if it flows freely. If it does there is dirt in the carburetor, and the carburetor should be removed, taken apart, and cleaned, although this work should be left to an experienced man unless you are positive of your ability to do this job successfully.

1482. If this pipe is not clogged and gasoline does not flow readily from the vacuum tank, tighten connections on pipe running from vacuum tank to intake manifold, and run the fingers carefully over the whole surface of the pipe to determine whether it is cracked or split, as a very slight air leak at any point may interfere with the engine suction on the vacuum tank. If there is any doubt as to the tightness of the connections, tape them carefully. If vacuum windshield cleaner is used, look for leaks in pipe to it.

1483. See that the air vent into the vacuum tank (Figure 61), is clear, testing it by blowing into it. If clogged, run a fine wire through it. See that air vent on filler cap on rear tank is not clogged.

1484. If there is a gasoline strainer between vacuum tank and carburetor, clean it thoroughly.

1485. Disconnect pipe at vacuum tank running to rear tank, remove strainer at former point, and clean it if dirty. Blow through pipe running to rear tank. If it seems clogged and can not be cleared with the mouth, use compressed air on it, but first remove the filler cap on the rear tank to facilitate flow of air through pipe.

1486. Drain a little gasoline from the carburetor and note if there is any water in it (water is heavier than gasoline and sinks to the bottom). If so, drain a half pint of gasoline from the carburetor to remove water.

1487. If the carburetor can be flooded and the ignition is not at fault, see that the auxiliary air valve (if there is one) is not stuck open. If it is, pull it closed and engine should start. If this valve is provided with a dash pot, its sticking is due to dirt in the carburetor. Drain about a half pint of gasoline from the carburetor to remove dirt, and if this does not cure the trouble, the carburetor may have to be taken apart and cleaned; although mostly the carburetor will clean itself, if given time. Drain all fuel from the rear tank and strain it to prevent a recurrence of this trouble. (See paragraph 912.)

1488. If the carburetor is not provided with an auxiliary air valve, some of the passages or jets may be clogged. It is best to have an experienced man clean the carburetor.

1489. Examine the throttle shaft carefully, noting whether it turns when the hand lever or accelerator pedal is moved. If it does not turn throttle shaft in the direction of closing as far as it will go, tighten defective linkage.

1490. See that the carburetor has not been thrown out of adjustment. Check adjustments as described under Carburetors, paragraph 915.

IGNITION SYSTEM FAULTS

1491. If ignition system is at fault, note whether lights are very dim; if so, the battery is probably run down. It should supply sufficient current for ignition as long as lights are brighter than dull red. For full details see All Lights Dim, paragraph 1310.

1492. Note whether ignition or lighting switches have been left on for some time thus allowing battery to run down. Several hours should be required unless the battery was weak to begin with. Otherwise, see paragraph 1135 for causes of run-down battery.

1493. If lights are bright, turn lights off and read ignition draw on ammeter with breaker points closed. Less than 1½ to 3 amperes with ignition switch on indicates a loose or dirty connection in the low-tension ignition circuit; a reading greater than normal indicates a ground and no reading shows that the circuit is open, including failure of the ignition-switch points to make contact. If the ammeter reads discharge, with breaker points open.

there is a ground. If the ammeter test just made indicates a ground, examine the wire running from breaker mechanism to coil.

1494. Not only should the insulation on this wire be examined, but the wire ends should also be studied. If the ends are not provided with terminal lugs, but the strands of wire are simply wrapped around the terminal post, a single stray strand may be causing the trouble.

1495. Sometimes a wire that is too large will produce a ground at the terminal, whereas a wire of correct size will not. If the ammeter shows discharge with breaker points open, and a ground is not found, the condenser is punctured and a new condenser should be installed. However, if a new condenser is not available, the old one may often be repaired by taking it apart carefully, cutting out the burned portions and cutting the tin foil back 1/8 inch from any paper edges which have been cut. Re-assemble condenser, and wrap in paper or tire tape if the old covering is defective.

1496. If the ammeter indicates a loose or open connection, examine the following wires at their terminals for these faults: Breaker mechanism to coil; coil to ignition switch; ignition switch to ammeter; ammeter to starting switch; starting switch to battery. Tighten all loose connections and clean all dirty connections.

1497. Inspect the high-tension wire running from the coil to the central terminal on the distributor. If insulation is defective or doubtful replace wire. As a check, crank the engine and watch for sparks jumping from this wire to some part of the engine. See that the terminal connection of this wire to the coil is not standing too close to the coil case (if the coil case is metal); if it is, bend it away.

1498. Examine the breaker mechanism for adjustment and pitting, and treat as described in paragraph 1156. It should be noted that the breaker points are not likely to be too far apart unless the breaker lock-nut or lock screw has become loose. They may, however, be too close together due to wear of the breaker mechanism, making adjustment necessary. Pass a piece of paper between the points to clean them, as it is barely possible that a particle of metal or carbon has lodged between them. Sandpaper is preferable to plain paper, or use a fine file. Tighten all terminals on the breaker mechanism, including the condenser terminals. If the position of the breaker cam is adjustable, as described in paragraph 1168, try to turn it with the fingers, if it turns readily retime the ignition as described in paragraph 1163. See that spark advance mechanism is in working order.

1499. Before making any repairs to the breaker mechanism as described in the preceding paragraph, detach the high-tension wire running from the coil to the central distributor terminal at the coil. Obtain a wooden-handled screwdriver, and hold its shaft about 1/4 inch from this terminal, while the point of the screwdriver is grounded. Have the engine cranked either by hand or by starter. Hot, regular sparks not only indicate that the breaker mechanism is all right, but the whole low-tension system and the spark coil are in good condition, therefore the defect must be in the main high-tension wire, or see paragraph 1509.

1500. If breaker mechanism and coil are all right, examine the distributor and rotor arm carefully for cracks and other mechanical defects, replacing defective parts. Clean all dirt from inside and outside of distributor. If distributor track is badly worn, it may be turned down in a lathe, although often replacement is cheaper.

1501. If coil is defective, the low-tension circuit may be in good order, but no spark or a weak spark will be obtained at the high-tension terminal on the coil.

1502. If sparks are obtained, as described in the third preceding paragraph, and previous tests have proved that the fuel system is all right, then examine the following points:

1503. Check compression as described in paragraph 614. If any compression at all is noted, the engine should start.

1504. Check spark timing as described in paragraph 1163. If spark timing is found to be incorrect, look particularly for slippage or disconnection of spark advance linkage, examining all parts carefully from steering wheel to ignition unit.

1505. Check valve timing as described in paragraph 654.

1506. Remove spark-plugs and clean porcelains or wipe them carefully if they are clean. Carbon, oil, or moisture on the porcelain or between the plug points will prevent starting.

SPECIAL STALLING TROUBLES

1507. The following special cases should also be noted:

1508. If the engine refuses to start when it is very cold, see Engine Starts Hard, paragraph 1522.

1509. If any parts of the high-tension ignition system have become covered with water due to careless washing, a heavy rain storm or a leak in the top of the radiator, wipe the parts dry. The distributor should be wiped inside and outside, all spark-plug porcelains should be wiped, and so should the high-tension wiring.

1510. When an engine stalls or fails to start after being exposed to moisture, wet wires must be kept in mind as a possible cause. Wet wiring is not a common trouble when the high-tension wiring is new, but is common after the wiring has been in use a year or so. If the insulation is rotten or porous, wet wiring trouble should be expected. The car should be protected as much as possible against driving rainstorms, damp garages, and the like.

1511. It should be explained that wet wiring causes stalling of the engine because all the damp wiring provides a path for the high-tension current.

Mostly, the car will fail to start soon after being exposed to wet weather; but sometimes 48 hours may elapse before the moisture which has settled on the wiring has permeated it sufficiently to cause stalling.

1512. Sometimes the simplest remedy is to allow the car to stand until the wires dry, hours or days are required, according to circumstances. Otherwise the wires must be removed and dried in an oven. Before removing the wires, tie them together with a string (consecutively from front to rear) so that it will be easy to replace them without danger of mixing up the wires running to the various spark-plugs. Then remove the distributor cap, and detach the brackets which support the high-tension wiring on the engine, lifting the whole assembly clear. If the oven is too hot, the wiring is likely to be damaged. The correct temperature is that of boiling water or a little below; in other words, a *cool* oven. How long the wiring must be left in the oven depends on circumstances, but in most cases an hour should be sufficient, and if the wires are not very wet, 15 minutes may be enough.

1513. When wet wiring trouble has been experienced it is time to re-wire the high-tension system completely.

1514. If the valves have just been ground, see that all valves are properly adjusted, and not too tight.

1515. If a liquid carbon remover has just been used, diffiulty is occasionally experienced in starting. If so, remove the spark-plugs and wipe the porcelains dry, or dip the plugs in gasoline and touch a match to them (out-doors of course).

1516. If the engine refuses to start when very hot, allow it to cool.

1517. If the breaker mechanism has just been inspected, see that you have not forgotten to put the rotor arm back in place.

1518. If the timing chain has not been adjusted in 10,000 miles: Check spark timing (paragraph 1163), and valve timing (paragraph 654).

1519. If the breaker cam turns freely when touched with the fingers, there is a break somewhere in the ignition drive.

1520. If the temperature is below freezing and the engine is not receiving a proper mixture, the fuel system may be clogged with ice instead of dirt, as described in paragraph 1480. Pipes should be all right when thawed out, although rarely the freezing may cause them to leak.

1521. If mixture is too rich and the cause is not apparent, the float may be stuck at the bottom of the vacuum tank. Remove the pipe running from vacuum tank to carburetor and if it is wet inside with gasoline, disassemble vacuum tank and examine as described in paragraph 906. In this case removal of suction pipe between vacuum tank and carburetor should permit engine running, thus proving cause of trouble.

ENGINE STARTS HARD

1522. Symptom—Engine starts hard.

1523. Note: The engine starts hard if it must be cranked more than two or three turns. For Ford ignition troubles, see paragraph 1713.

1524. Causes—(1) Choke does not work properly. (2) Throttle setting incorrect. (3) Spark setting incorrect. (4) Breaker points too far apart. (5) Spark-plug points too far apart. (6) Battery weak. (7) Valves leaky. (8) Low-speed carburetor adjustment incorrect. (9) Air valve adjusted for too weak a mixture. (10) Low-speed jet or jets clogged. (11) Magneto magnets weak. (12) Cold weather. (13) Car laid up for several weeks.

1525. Cure—1. Modern cars depend upon a choke mechanism to facilitate starting. As a rule, the choke is brought into action by pulling out a button on the instrument board. After the car has been in use for some time it sometimes happens that something goes wrong with the choke mechanism. Therefore, whenever hard starting is experienced, examine the choke mechanism carefully to be sure that pulling out the button brings the choke into full action. If not, make any obvious repairs or adjustments; otherwise see your repairman.

1526. Sometimes the choke works too well and provides the engine with a mixture too rich for easy starting. Therefore, if the choke mechanism appears to be in good condition, try pulling it out part way instead of all the way, decreasing the distance with rising atmospheric temperature, and pulling it out all the way only in cold weather.

1527. If the choke mechanism is defective, pending its repair, starting may be facilitated by flooding the carburetor (see paragraph 935), or by priming the engine by introducing a teaspoonful of gasoline into the petcock on each cylinder.

1528. Cure—2. The throttle should not be opened too far; never more than one-quarter of the distance on the steering wheel quadrant, and rarely more than one-eighth.

1529. Cure—3. The spark, as a rule, should be advanced half-way on older cars; all the way on most modern cars.

1530. Cure—4. Treat breaker points as described in paragraph 1156. If the breaker points have not been adjusted in 3,000 miles or more they should be examined. Hard starting due to breaker points too far apart is generally accompanied by bucking at low speed in high gear.

1531. Cure—5. Spark-plug points should be about $\frac{1}{32}$ inch apart. If the points have not been set up in several thousand miles, they should be examined.

1532. Cure—6. If the lights are fairly bright, the battery is not at fault as far as the ignition is concerned, although hard starting may be due to slow cranking (see paragraph 1233).

1533. Cure—7. Test compression; see paragraph 614 for further details.

1534. Cure—8. If the low-speed adjustment on the carburetor is much too rich or too lean, hard starting may result, although in many cases the choke is independent of the low-speed adjustment. For adjustment, see paragraph 913.

1535. Cure—9. If the carburetor is equipped with an auxiliary air valve, and this valve is adjusted for a high-speed mixture much too weak, it may allow too much air during the starting period; although if this happens the mixture should be much too weak for satisfactory running. (See paragraph 913.)

1536. Cure—10. Sometimes complete or part clogging of the low-speed jets will result in hard starting coupled with a weak mixture at low speeds. The remedy is to remove the jets and clean them, although most motorists prefer to have this work done by their repairmen.

1537. Cure—11. Magneto magnets need recharging. If the car is equipped with a magneto and the magnets have not been charged in two or three years or more, and there seems to be no other explanation of the hard starting, take your car to an electrical expert or your repairman and have the magnets recharged. On motor-trucks equipped with an impulse coupling on the magneto to render starting easy, there may be some defect in this coupling. However, expert advice should be obtained at this point.

1538. Cure—12. On cars equipped with special arrangements for heating the starting mixture, such as some Franklins, Packards, and Lincolns, any defect in the mechanism may cause hard starting, particularly in cold weather. It is beyond the scope of this book, however, to discuss these mechanisms fully. In zero weather any car without some such special arrangement is likely to start with difficulty. A permanent and completely satisfactory remedy is the installation of an electric mixture heater, which is simply some form of electric heating device placed in the intake manifold and supplied with current from the battery. Easy starting in the coldest weather then merely consists in closing the heater switch for a few seconds before cranking the engine.

COLD ENGINE

1539. If an engine refuses to start on a very cold day, flood the carburetor. If the engine does not start immediately, do not repeat the process, but prime the engine, pouring about a tablespoonful of gasoline into the petcock in each cylinder. Gasoline may usually be conveniently obtained for this purpose by draining some from the carburetor into a glass or a small can, or the oil can may be emptied and filled with gasoline, and the fuel squirted into the petcocks. If the petcocks are clogged with carbon, remove them and inject the gasoline through the openings. If the engine has no petcocks, remove the spark-plugs, and inject the gasoline through these openings. If the main air opening to the carburetor is at the top instead of at the side or bottom, a simpler method of priming the engine is to pour a quarter or third of a glass full of gasoline into this opening.

1540. If the engine refuses to start immediately after priming (and assuming that the trouble is not a case of stalled engine, see paragraph 1468), obtain a bottle of denatured ether at a drug store, and prime the engine with it; or if the engine is very cold, a better method is to shut off the gasoline, drain the carburetor, remove the cover to the float chamber and fill the chamber full of denatured ether, replace the cover, turn on the gasoline and start the engine just as though it were a hot day in August. If the engine fails to start, the difficulty is not coldness, but ignition trouble. (See paragraph 1491.) Modern drug-sore gasoline is usually no better than ordinary gasoline.

1541. If ether is unavailable, drain the water from the cooling system, and fill the system with boiling hot water. If hot water is not available, remove the spark-plugs, pour a small quantity of gasoline over them, and touch a match to them. As soon as the flame has subsided, replace the hot plugs and try starting the engine without delay. The author has not tried this method and can not vouch for it; but in any case it is offered only as a last resort.

1542. A cold engine may often be started by towing the car in high gear.

1543. Cure—13. If the car has been standing for several weeks or months, hard starting may be due to the evaporation of the more volatile portions of the gasoline. Shut off gasoline, drain carburetor dry, and turn on gasoline again, thus obtaining a fresh supply from the vacuum tank. If engine fails to start, prime it. If it still refuses to go, get some fresh gasoline, shut off gasoline, drain carburetor, remove float chamber cover, and fill with fresh gasoline. Once an engine is warmed up on the fresh gasoline it will probably use the gasoline remaining in the tank without difficulty, otherwise the rear tank must be drained and the fresh gasoline put in.

ENGINE LACKS POWER

1544. Symptom—Engine lacks power.

1545. Causes—(1) Brakes dragging. (2) Oil supply low. (3) Lubrication system defective. (4) Water low. (5) Cooling system defective. (6) Valves or pistons leak. (7) Mixture too weak or too rich. (8) Spark retarded or improperly timed. (9) Breaker needs adjusting. (10) Wet wires. (11) Valve timing incorrect. (12) Clutch slips.

1546. Other causes of lack of power are defective automatic spark-advance mechanism; weak valve springs; sticking valves; dirty muffler or muffler with loose baffle plates; old high-tension wiring; leakage of exhaust into intake manifold.

1547. Cure—1. See that hand brake is off all the way. If brakes have recently been adjusted, feel brake drums, and if they are sizzling hot, brake adjustment is too tight. Note that the adjustment may be too tight with a full load and just right with a half load, (see paragraph 2209).

1548. Cure—2. Sometimes, loss of power will be noted if oil level gage registers less than half full, but lack of oil supply can not be the trouble as long as pressure gage is normal. If oil supply is low, add oil as soon as possible, as the engine is in danger of ruin, and drive slowly until oil is added, but do not drive at all if the supply is so low that no pressure is shown on the gage.

1549. Cure—3. See Oil Pressure Low (paragraph 732), or No Oil Pressure (paragraph 741).

1550. Cure—4. Examine water level in radiator, but if engine is very hot do not add water until it cools. For full details, see Engine Overheats, paragraph 1559.

1551. Cure—5. Cooling system defective, see paragraph 1559.

1552. Cure—6. Valves or pistons leak. Test compression as described in paragraph 614. High oil consumption will be noted if there is leakage past the piston rings. (See paragraph 670.)

1553. Cure—7. Mixture too weak or too rich. See paragraph 913 regarding carburetor adjustment.

1554. Cure—8. See that spark has not been retarded by mistake. Look for slippage and breakage in spark linkage and defect in ignition unit drive, including loose timing chain. Check spark timing as described in paragraph 1163. A retarded spark will cause overheating, whereas a spark much too far advanced will cause loss of power accompanied by knocking whenever the throttle is opened.

1555. Cure—9. See paragraph 1156.

1556. Cure—10. Wet wires may cause loss of power, although missing or stalling are more likely to be the symptoms noted. (See paragraph 1509.)

1557. Cure—11. Check valve timing (see paragraph 654).

1558. Cure—12. Clutch slips (see paragraph 1819).

ENGINE OVERHEATS

1559. Symptom—Engine overheats.

1560. Causes—(1) Water low. (2) Cooling system defective. (3) Spark retarded or improperly timed. (4) Oil supply low. (5) Lubrication system defective. (6) Mixture too rich. (7) Valve timing incorrect. (8) Too much running on low gear. (9) Weather excessively hot or cooling system inadequate. (10) Engine badly carbonized.

1561. Other causes of overheating include collapse of lower hose connection if pump suction is strong, remedy being new hose and if necessary a coil of wire inside hose to support it; crack in cylinder block which permits exhaust to enter cooling water; fan blades bent or reversed; absence of baffle plate in top of radiator permits rapid loss of water through vent pipe.

1562. Note: A radiator thermometer is desirable if overheating trouble is always to be discovered before the engine is harmed, but in addition it is necessary to form the habit of watching it. If a radiator thermometer is not fitted, the first symptom may be loss of power, although in many cases the heat may be felt or "smelled." In removing the radiator cap keep the face well away from it, so that if a puff of steam occurs when the cap is taken off no damage will be done.

1563. Cure—1. Low water due either to evaporation or leakage will cause overheating. Fill radiator at first opportunity. If water level is out of sight, and engine is hot, fill very slowly—at the rate of about 1 gallon a minute—until water level can be seen. If water is not immediately available, allow engine to cool, then drive slowly, coasting with ignition off at every opportunity. As soon as water boils, stop and allow engine to cool. These precautions may be ignored if distance to water is short, but in no case operate an engine after a marked loss of power, missing or knocking is observed. After filling, look for leaks, particularly around hose clamps; tighten any clamps that permit leaks. If radiator or cylinder casting leaks, have cooling system filled with a good radiator compound, or have permanent repairs made. Do not use cornmeal or other home-made remedies unless there is no other alternative.

1564. Cure—2. Defects in the cooling system include:

(A) Loose or broken fan belt.
(B) Broken pump or pump drive.
(C) Dirty radiator.
(D) Clogged water passages.
(E) Cylinders filled with sediment.
(F) Defective thermostat.
(G) Defective radiator shutter.

1565. The foregoing troubles may be remedied as follows:

A—Tighten fan belt, or replace if broken. Belt should be tight enough so that a slight pull is required to turn fan by hand with engine stopped, but belt should not be tight enough to strain fan bearings. Pending adjustment or replacement, if the cooling system is ample and the weather is not too warm, overheating is not likely even with fan belt missing. With less adequate cooling systems or in warmer weather, overheating when the fan belt is missing is extremely unlikely if the speed is not allowed to fall below 25 miles an hour. In hilly country, provided that the hills are not excessively long, overheating at speeds below 25 miles an hour is rare if all down grades are taken with ignition off and clutch out, or ignition off, clutch in and throttle closed. If the grade is slight the former method is preferred. In average rolling country by taking advantage of all down grades as described the engine may be kept at a lower temperature without the fan working than with the fan working if usual driving methods are used.

B—In looking for cooling troubles if the bottom half of the radiator is somewhat warm it indicates that something has happened to reduce the rate at which the water circulates; but if the lower half of the radiator is cold it indicates complete stoppage of the circulation. The former suggests a loose fan belt, partly clogged passages or somewhat dirty radiator or closed radiator shutter; the latter suggests a broken pump, completely clogged passages, defective thermostat, or radiator with much sediment in it. Examine pump drive and disassemble pump, but first follow directions C, D and G.

C—Radiator may be considered dirty if it has not been cleaned in 5,000 or 10,000 miles. To check condition break lower hose connection and with engine running note whether flow is free. If not, radiator must be cleaned, see paragraph 813.

D—Put in new hose if present hose is at all decayed.

E—Remove cylinder head and clean out water jackets as last resort after all other possible troubles have been checked.

F—If thermostat and cylinders are hot but radiator is cold, the thermostat has failed to open. Consult your repairman.

G—A radiator shutter which fails to open will cause overheating. If the shutter is manually controlled the operator may forget to open it, or the linkage may fail or if it is thermostatically controlled the thermostat may fail. Check the two former points and consult your repairman regarding the latter.

1566. Cure—3. A late spark—whatever the cause, will produce overheating, and loss of power, see paragraph 1163.

1567. Cure—4. Add oil if required.

1568. Cure—5. See paragraph 732.

1569. Cure—6. See paragraph 913.

1570. Cure—7. See paragraph 654.

1571. Cure—8. Wide-open throttle when in low gear, whether negotiating mud, sand, or long mountain grades, may cause overheating, and the remedy is to close the throttle as much as required to prevent overheating, or stop and allow engine to cool.

1572. Cure—9. Extremely hot weather, coupled with adverse road conditions, may cause overheating unless the cooling system is exceptionally ample. Bear in mind that the smaller the throttle opening the less the danger of overheating.

1573. Cure—10. If the engine is so badly carbonized that it runs for a few revolutions after the spark is shut off, and has been doing so for some time, the carbon deposit may be so heavy as to cause overheating. But it should be added that overheating due to excessive carbon is not a common trouble.

1574. If the weather is very cold, overheating may occur while the remainder of the cooling system is freezing, although this will not occur if an anti-freezing solution is used. However, with water alone, slush is likely to form in the coldest part of the system, soon completely shutting off circulation and thus causing the water in the water jackets to boil, the steam escaping to the top of the radiator, whence it flows out of the vent pipe.

ENGINE KNOCKS

1575. Symptom—Engine knocks.

1576. Note: It must be emphasized that there are few knocks which the motorist can cure, and the following information is offered mainly to enable the motorist to determine what steps must be taken to avoid damage to the engine.

1577. Cause—1. Carbon knock. A sharp, metallic sound most noticeable in climbing steep grades on high gear, especially when the engine is heated. It may occur in one or more cylinders, depending on whether one or more cylinders are badly carbonized.

1578. Cause—2. Spark knock. Sounds like a carbon knock. All cylinders should knock equally. This is noticeable with throttle open and engine pulling hard and disappears with closed throttle or spark retarded.

1579. Cause—3. Loose connecting rod bearing. A sharp, clear sound as though the crankshaft were being hit with a hammer. Its loudness depends on how loose the bearing is. It is heard when the engine is running idly down hill, or when the engine is allowed to decelerate after speeding up.

1579A. Cause 4. Loose main bearing. A dull thud noticeable when the car is pulling hard on high gear, either ascending a hill or upon opening the throttle quickly, or when running fast with spark advanced. A loose cylinder block on crankcase is similar.

1580. Cause—5. Loose flywheel. Set throttle so that engine runs at a speed equal to about 15 miles an hour in high gear. Switch off the ignition and when engine has almost come to rest, switch the ignition on again. A distinct knock at this moment indicates a loose flywheel.

1581. Cause—6. Loose pistons. A general clatter, in addition to that produced by the valves, most noticeable when the engine is speeded up idly indicates loose pistons and worn cylinders.

1582. Cause—7. A slight knock, about as loud as that produced by a valve badly in need of adjustment, may indicate a loose wristpin. If it is confined to one cylinder, the knock will disappear when the spark plug on this cylinder is short-circuited with a screwdriver.

1583. Cause—8. Sometimes a sharp and powerful hammer will be caused by a weak mixture. Sounds like a carbon knock.

1584. Cause—9. High-compression knock. Caused rarely by compression being too high. Not noted when throttle is partly or fully closed. Sounds like a carbon knock.

1585. Cause—10. Engine hot.

1586. Cause—11. Engine lacks oil.

1587. Cause—12. Exhaust valve stuck open or intake valve stuck closed. Heavy hammer at all speeds with throttle open, accompanied by pronounced missing. Also see Cause 13.

1588. Cause—13. Light tap at all speeds usually indicates a valve badly in need of adjusting. Heavier tap if valve is stuck.

1589. Cause—14. For other knocks, see Cure 14.

1590. Cure—1. Have carbon removed. For further details see paragraph 680.

1591. Cure—2. Check spark timing, see paragraph 1163.

1592. Cure—3. Have connecting-rod bearings adjusted (see paragraph 663). Other work likely to be necessary at this time includes new wristpins, new piston rings, adjustment of main bearings, and thorough cleaning of lubricating system.

1593. If connecting-rod knock develops very slowly over a period of days it is permissible to run the engine as long as the knock can not be heard more than a few feet from the car, although the sooner the knock is cured the better.

1594. If the knock develops quickly and becomes noticeably louder in a few minutes, examine the oil pressure gage. If the pressure is low, see paragraph 732. If the cause of low oil pressure is removed the knock will probably not become louder. The connecting-rod should be adjusted at the first opportunity; meanwhile, the engine may be run as long as the knock is slight. If cause of low oil pressure is not remedied, do not attempt to run engine after knock can be heard 75 feet from car.

1595. If the oil pressure is all right, do not attempt to run the engine after the knock can be heard 50 to 75 feet from the car. To do so is to run the risk of a bent crankshaft or a broken crankcase; the latter is caused by the rod breaking loose from the crankshaft and poking its way through the crankcase.

1596. If the loose connecting-rod develops suddenly approaching sledging sledge hammer loudness within a few seconds the engine should be shut off as quickly as possible and should not be run again until the rod is repaired. Neglect of this advice is almost certain to result in a broken connecting-rod, a bent crankshaft, or a broken crankcase.

1597. Cure—4. It is permissible to run an engine with a loose main bearing as long as the knock is barely perceptible, but if the knock becomes louder continued running is likely to result in a bent or broken crankshaft. For further information, see Cure 3.

1598. Cure—5. A loose flywheel is not a common trouble, but the engine may be run as long as the knock is slight. If the flywheel is accessible, tighten all nuts on it carefully. Continued running with a loose flywheel may result in serious damage to crankshaft, flywheel, or clutch.

1599. Cure—6. See paragraph 670. The knock may be reduced by using heavy cylinder oil, although this will result in increased carbon deposit.

1600. Cure—7. Wristpin knocks may be ignored as long as they are slight, but repairs should be made when the noise becomes very noticeable. If wristpins are repaired when connecting-rod bearings are adjusted, trouble from this source will be rare.

1601. Cure—8. To determine whether the knock is due to a weak mixture, see that the carburetor is properly adjusted (see paragraph 913), otherwise look for dirt in the carburetor. If the knock disappears the trouble is a weak mixture. No harm, beyond loss of power, occurs when the engine is suffering from a weak mixture knock.

1602. Cure—9. A high-compression knock may be cured by increasing the volume of the combustion chamber; this in turn may be accomplished by placing a thick gasket between cylinders and crankcase (when the two are separate) or by using shorter connecting-rods, or pistons with reduced distance from piston head to wristpin. A simpler remedy is to use a good high-compression fuel designed to prevent detonation. When the mixture in the cylinder detonates, it explodes much more rapidly than when it burns normally, the noise or knock heard being due to cylinder wall vibration caused by excessively high, momentary, fluctuating pressures. The mixture detonates more readily as the compression is increased, as the spark is advanced or as the amount of carbon increases. Hence, in a broad sense, carbon, spark, and high-compression knocks are one and the same.

1603. Cure—10. If the engine is overheated, the knock will probably disappear when it has cooled.

1604. Cure—11. Lack of oil may cause knocking which will ease when the lubrication is adequate.

1605. Cure—12. If an exhaust valve remains open due to sticking or to breakage of the spring, the complete lack of compression in this cylinder will cause the engine to run so lamely that a heavy hammer may appear, accompanied by missing. The knock will cease as soon as the valve trouble is remedied. Complete lack of compression may also be caused by failure of an intake valve to open due to excessive clearance between push rod or valve stem, or to breakage of push rod. Examine clearance of all valves. For further details see paragraph 638. If overhead valves are used, see that rocker shafts are tight.

1606. Cure—13. Examine clearances of all valves and note whether all valves are closing properly. Adjust any valves on which clearance is excessive. For further details see paragraph 638. A valve tap is not likely to do any harm.

1607. Cure—14. All the usual knocks have been described in the previous paragraphs, yet there are so many others that it is not possible to describe them all, although there are a few that must be mentioned. Also see Engine Hums, paragraph 1633. An elusive engine knock may be caused by a loose bolt holding the engine to the frame, and various other loose parts may knock such as the generator, starter, exhaust pipe, mud splasher pan, steering gear, and others.

1608. A loose gear may knock. A magneto, generator or camshaft gear may be loose on its shaft, in which case the knock should be heard coming directly from the gear. Continued operation of the engine may lead to trouble, and it is advisable to have your repairman fix this defect at the earliest possible moment. If the noise is due to worn gear teeth, a new gear will be required to eliminate the noise.

1609. Excessive end play in the camshaft may cause a slight knock. Sometimes there is an adjustment to cure this noise. Excessive end play in the crankshaft, or side play in connecting-rod bearings, and bent connecting-rods may cause knocks. These defects are mentioned merely for the reader's information, but the trouble should be diagnosed and cured by an experienced man.

1610. If the shaft which drives the generator, water pump, or magneto has a coupling, a slight knock may be heard when these parts wear or get out of adjustment. Remedy any obvious defect such as loose screws and nuts. The noise is not likely to do any harm if caused by wear only.

1611. If a fan belt has a metal coupling, any defect in its alinement may produce a musical knock. If the remedy is not obvious, install a new fan belt. Endless fan belts should be used whenever their installation is possible. When this trouble is suspected, slip the fan belt off of its pulleys. If the knock disappears the source of the trouble has been detected.

1612. A loose timing chain may produce a rattling knock by striking its case. Adjust or replace. (See paragraph 659.)

OTHER ENGINE NOISES

1613. Other noises which come or appear to come from the engine include: (1) Engine knock caused by missing muffler bracket bolt. (2) Compression knock due to recently installed connecting-rod being too long. (3) Engine knock due to connecting-rod striking some nearby part such as an oil pipe. (4) Knock due to eccentric camshaft gear. (5) Knock due to frayed fan belt striking radiator. (6) Knock due to valve guide loose in block. (7) Knock due to shoulder on push rod striking edge of push-rod guide. (8) Knock due to absence of oil hole or oil hole in bearing not registering with crankshaft or clogged oil passage to main or rod bearing. (9) Knock due to one blade missing from fan. (10) Knock due to broken tooth on camshaft gear. (11) "Main-bearing" knock due to loose cylinder head or cylinder block. (12) "Bearing" knock due to: Piston ring gaps lined up; loose bolt in muffler; piece of foreign matter lodged in oil relief valve; loose cap screws on camshaft gear; loose motor support arm or cross member. (13) Valve knock at high speed due to weak valve springs. (14) "Noisy tappet" knock due to loose spark-plug. (15) "Loose wristpin" knock caused by loose hold-down bolts on push rod guides. (16) "Wristpin" knock caused by bent oil pipe touching push rod. (17) "Wristpin" knock caused by cam striking projection on crankcase which was then chiseled off. (18) "Timing gear" growl caused by vibration of oil-gage line, cured by securing pipe with rubber cleats. (19) Whistle due to pin hole in one piston. (20) Whistle due to rough fan belt. (21) Shriek in fan due to timing chain too tight. (22) Squeak under hood due to starter gear running in oil, remedy being to drill oil drain hole. (23) Generator squeak cured by adjusting and oiling fan belt.

ENGINE BUCKS

1614. Symptom—Engine bucks.

1615. Cause—Engine misses at low speed.

1616. Cure—Bucking may be defined as a jerky operation of the engine when running slowly in high gear, due to missing. See that breaker points are in good condition, as in paragraph 1156.

ENGINE BACKFIRES

1617. Symptom—Engine backfires.

1618. Note: Ignition of charge in intake pipe causes explosions through carburetor. Backfiring is always accompanied by missing whenever the backfiring occurs. Backfires are sharp, slight explosions issuing from the carburetor.

1619. Causes—(1) Engine cold. (2) Spark retarded. (3) Heating device not working. (4) Mixture weak. (5) Dirt in carburetor. (6) Leakage through intake valve. (7) Excessive clearance on exhaust valve.

1620. Cure—1. Backfiring should disappear when engine is warm. Cure 2. Advance spark. Check spark timing (paragraph 1163), if engine lacks power or overheats. Retarded spark is only likely to cause backfiring while engine is warming.

1621. Cure—3. Examine exhaust heating device. See that all piping is in place, and if there are any valves in the system, see that they permit heating of the intake air.

1622. Cure—4. A richer mixture is required in cold weather. For carburetor adjustment see paragraph 913.

1623. Cure—5. Dirt in fuel system will cause backfiring. See paragraph 1480. Backfiring may be noted only at high engine speed with normal running at low speed.

1624. Cure–6. Leakage may be due to lack of clearance on intake valve, or to excessive play between valve stem and guide, or to shoulders on intake valve. (See paragraph 632.)

1625. Cure—7. Excessive clearance on an exhaust valve will produce faint backfiring upon closing throttle. Examine clearance of all exhaust valves. For further details see paragraph 638.

MUFFLER EXPLOSIONS

1626. Symptom—Muffler explosions.

1627. Note: If the muffler is strongly constructed muffler explosions will do no harm, although if the muffler is weak it may be blown apart.

1628. Causes—(1) Intermittent ignition with throttle open. (2) After burning in muffler due to weak mixture.

1629. Cure—1. Missing caused by a defect in the ignition system may cause muffler explosions when running with throttle partly or fully open. (See paragraph 1407.)

1630. Muffler explosions when starting may be caused by turning on ignition after cranking engine, and the remedy is to turn on the ignition first.

1631. When running down hill with the car in gear and the ignition switch off, switching on the ignition with throttle partly or fully open will produce muffler explosions. Always switch on ignition with throttle closed. Then if muffler explosions are heard adjust carburetor and then adjust throttle stop on carburetor until engine idles at minimum speed.

1632. Cure—2. If slight muffler explosions are heard when running down hill with car in gear, ignition on and throttle closed, see that mixture is not too weak, paragraph 913, and see that spark is advanced all the way. Some cars may produce occasional muffler explosions under these circumstances, even after proceeding as described.

ENGINE HUMS

1633. Symptom—Engine hums.

1634. Cause—Timing chain or gear too tight.

1635. Cure—This trouble applies only if the timing chain or gear has recently been adjusted, and, of course, includes a car just received from the factory. Have your repairman loosen the adjustment, or see paragraph 659.

GEAR NOISES

1636. Symptom—Gear rattles.

1637. Cause—Loose or worn gear.

1638. Cure—For loose gear see paragraph 1608. If gear is worn, have it adjusted or replaced.

INTAKE LEAKS

1639. Symptom—Intake leaks.

1640. Cause—Leakage in intake pipe or around intake valve stems.

1641. Cure—If slight sucking noise in addition to that produced by carburetor is heard, look for leakage in intake pipe or around intake valve stems. The former will be continuous and the latter intermittent. Examine the intake valve stems for wear. Leakage in the intake pipe may not be audible, in which case search intake joints with a lighted cigaret while the engine is running. If the smoke is sucked in at any point there is leakage. The usual remedy is a new gasket at this point unless the screws holding the joint together are merely loose. in which case they should be tightened.

1642. Intake leakage is often accompanied by irregular running of the engine at low speed, particularly when idling, but irregular running may be due to other causes, so see paragraph 1402.

ENGINE IDLES IRREGULARLY

1643. Symptom—Engine runs irregularly when idle.

1644. Cause—Unequal explosions in the different cylinders.

1645. Cure—Few engines run with perfect regularity and slight irregular running or "rolling" is hardly worth correcting. See that all valves are tight and properly adjusted, that the low-speed carburetor adjustment is correct, that the exhaust heating system is working properly, that the breaker mechanism is all right, and that the spark-plug gaps are correct. Irregular running may also be due to intake leakage. See paragraph 1464.

EXHAUST LEAKS

1646. Symptom—Exhaust leaks.

1647. Cause—Leakage in the cylinders or in some part of the exhaust system.

1648. Cure—An exhaust leak may produce a loud, intermittent hiss or sound somewhat like an engine with muffler cutout open, but not so loud as a rule. The trouble should be readily detected by listening, or by feeling various suspected points for a blast of hot gas. The general cause is an open petcock. Examine screw in plug for tightness; if loose, tighten with a screwdriver. If petcock still leaks or refuses to remain closed, tap the plug with a hammer, and if this is not sufficient, remove the cock and hit the plug a hard blow. If there is leakage around the threads of the cock, turn screw up as tightly as possible. If after using the foregoing remedies, leakage persists, put in a new cock.

1649. If leakage occurs around a spark-plug, screw the plug in tightly. See that there is a copper gasket between plug and cylinder, unless the plug has a pipe thread.

1650. On the few cars equipped with plug caps over the valves, leakage may occur around the cap. Tighten the cap and see that there is a gasket between cap and cylinder. If a suitable wrench is not available use a hammer and a cold chisel. If the cap is very loose it will produce a slight musical rattle when the engine is running.

1651. Leakage of exhaust gas around the cylinder head gasket may be due to looseness in the cylinder head, and any loose cylinder-head nuts should be tightened. If this does not remedy the trouble a new gasket will be required.

HISSING SOUND

1652. Symptom—Hissing.

1653. Cause—Excessive leakage around intake or exhaust valves.

1654. Cure—New valves and new valve guides, or new valves with over size stems must be installed, see paragraph 632. This noise is distinct in some cases and in others resembles an intake or exhaust leak. It may also be mistaken for a knock. Consult your repairman. A hissing sound may also be produced by excessive leakage of gas past one or more pistons. If the trouble does not disappear after a time, consult your repairman, as the rings are probably defective, or the ring openings are in line, allowing the gas a straight passage to the crankcase.

ENGINE SPEED LOW

1655. Symptom—Engine speed low.

1656. Causes—(1) Dirt in fuel system. (2) Engine lacks power.

1657. Cure—1. If car can not be operated above a certain speed continuously, say 20 miles an hour, there is probably dirt in the fuel system, see paragraph 1478.

1658. Cure—2. Engine lacks power, see paragraph 1544.

Chapter XIV

FORD MODEL T IGNITION SYSTEM

1701. A separate coil for each cylinder (Figure 96), was a popular arrangement on many early cars. One end of each high-tension winding is directly connected to a spark-plug, the other end being grounded. One side of the battery is grounded and the other is connected to one end of each low-tension winding. The other end of each low-tension winding runs to a terminal on a device called a timer or commutator. The timer is equipped with a rotating brush which is grounded, the result being that as the brush rotates and makes contact with each terminal, current flows through the low-tension winding of the coil in circuit. The timer brush neither makes nor breaks contact with sufficient rapidity to produce good ignition and therefore a vibrator or trembler, magnetically operated, is placed on each coil. When the circuit is first closed by the timer brush, current flows through the primary coil until presently the magnetism is sufficient to draw down the trembler and break the circuit. At this instant a spark occurs at the plug. An instant later the trembler has made contact again and current

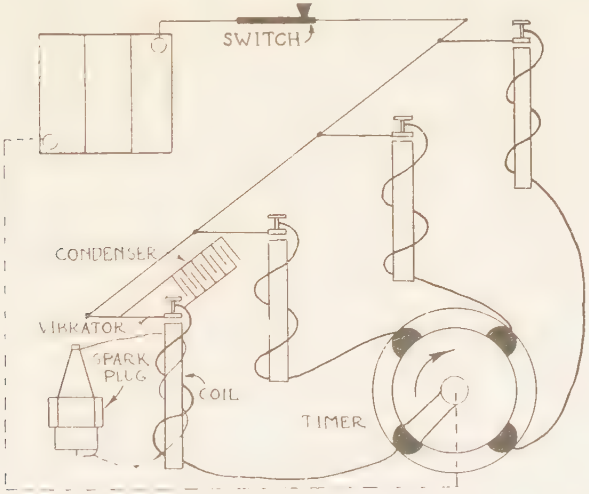


Figure 96.—Principle of Ford Model T ignition system. Each coil has its own condenser, although for simplicity only one is shown

flows through the primary and the circuit is broken again. This performance is repeated and a shower of sparks is delivered to the spark-plug as long as the timer brush makes contact with that segment. This system can hardly be considered as simple as the battery system and is open to the objections that all four tremblers must be kept in correct adjustment; even then the sparks to the different cylinders are not likely to be timed as accurately as if a breaker mechanism were used.

DESCRIPTION OF SYSTEM

1702. The ignition system used on the Ford Model T consists of a timer and separate coil units (Figure 97), but the source of current instead of being a battery, is a special type of magneto in front of the flywheel, which generates a current of about 14 volts, although the voltage increases somewhat with the engine speed. A number of permanent magnets are bolted to the front of the flywheel, and revolve with it. Just in front of these magnets are a number of coils, each wound around an iron core and all connected in series. One end of the system is grounded on the metal frame which supports the coils and the other end is connected to an insulated terminal in the top of the flywheel housing from whence current is delivered to the ignition system. There is a space of only $\frac{1}{32}$ inch between the magnets and the coils. It is plain that the rotation of the magnets past the coils must generate a voltage

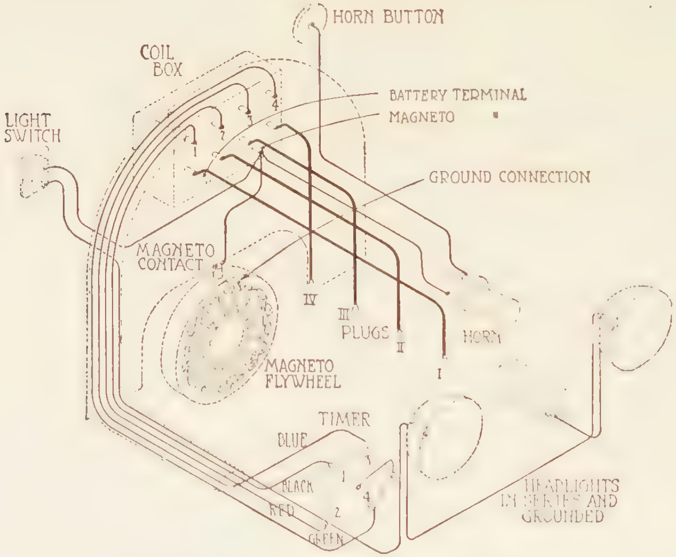

HORN BUTTON
COIL BOX
LIGHT SWITCH
BATTERY TERMINAL
MAGNETO
GROUND CONNECTION
4
3
2
1
MAGNETO CONTACT
IV
III
PLUGS
II
I
HORN
MAGNETO FLYWHEEL
TIMER
BLUE
BLACK
RED
GREEN
1
2
3
4
HEADLIGHTS IN SERIES AND GROUNDED

Figure 97.—Early Ford Model T wiring system, showing lights supplied by magneto

in the coils. The current produced is alternating, as is always the case when the current generating machine has no commutator, but this does not interfere with the working of the vibrators on the spark coils because they will function with current flowing in either direction.

1703. On Model T Fords equipped with electric starting and lighting the magneto is used only to supply ignition, but on Fords not so equipped the magneto is also used to operate the headlights and horn. Figure 97 shows an early wiring diagram. The terminal on the magneto is connected to a terminal on the coil box, and the wires running to lights and horn are also connected to this terminal. The two headlights are placed in series, double contact bulbs being used in both, while the terminal leading from one of the lights is grounded as shown.

1704. Some of the earlier Model T Fords were equipped with a combination horn and light switch, on the steering column, and resembling the usual horn switch except that it is larger. The connections are shown in Figure 98. Four wires run up to this switch, *A*, *B*, *C*, and *D*. *D* is the feed wire running from the common terminal on the coil box. When the switch makes contact between *D* and *C*, the horn blows, when contact is made between *D* and *B* the headlights are on full, and when it makes the circuit between *D* and *A* the headlights are dimmed.

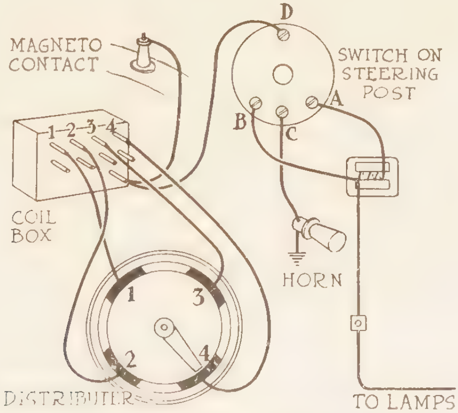


Figure 98.—Ford Model T magneto headlight wiring used on some of the earlier models

1705. The four Model T Ford coils are carried in a box on the dash. Each coil has three brass terminal points, two on the front and one on the bottom, which connect with spring terminal clips on the box. One or all coil units may be lifted out without removing any wires or connections, while the mere act of placing the unit back in the box makes the connections. The lower terminal point on the front of the coil unit (Figure 97), is the one through which the high-tension current flows to the spark-plug. The upper terminal on the front connects with a terminal on the timer, while the terminal on the bottom of the coil connects with the magneto.

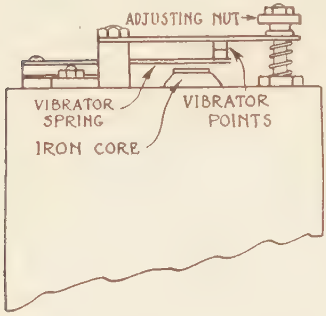

ADJUSTING NUT
VIBRATOR SPRING
VIBRATOR POINTS
IRON CORE

Figure 99.—Vibrator mechanism on top of Ford Model T coil

1706. Figure 99 shows details of the vibrator on top of a Ford coil unit. When the current flows through the low-tension winding the iron core is magnetized and attracts the vibrator spring, to it, thus separating the points and breaking the circuit. The vibrator points should be smooth and meet squarely. If they become pitted they may be smoothed up by inserting a fine, flat double-faced file between them. If the points are so badly worn that they can not be trued satisfactorily, these parts should be replaced. The distance between the points should be a trifle less than $\frac{1}{32}$ inch when the vibrator spring is held down against the iron core. Adjustment is effected by turning the nut shown, after which the lock-nut above should be turned up tight.

1707. Some drivers prefer to add a battery to the Ford ignition system for easy starting by hand, switching to the magneto as soon as the engine is under way. Either four dry cells or a 6-volt storage battery may be used. Inasmuch as the magneto supplies upwards of 12 volts it might be thought that a similar battery voltage would be required, but practical experience shows that this is not necessary. It will be noted that the Ford ignition switch lever may be moved to right or left of neutral; to the left connects the magneto, to the right connects the battery if there is one. One terminal of the battery should be connected to the vacant terminal on the coil box, as shown in Figure 97; the other side of the battery should be grounded.

TIMER

1708. Figure 100 shows construction of the timer. It will be seen that the inner surface of the timer consists of a cylindrical fiber ring, in which are set four metal segments, with connecting wires running to the low-tension windings of the four coils. The timer brush consists of a metal roller mounted on a pivoted arm the other end of which is provided with a coil spring

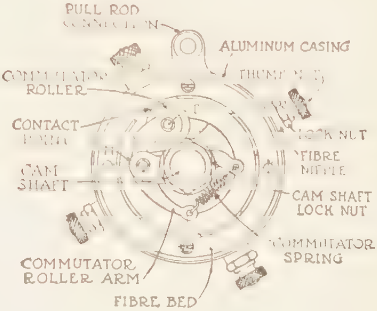

PULL ROD CONNECTION
ALUMINUM CASING
COMMUTATOR ROLLER
THUMB NUTS
CONTACT POINT
LOCK NUT
FIBRE NIPPLE
CAM SHAFT
CAM SHAFT LOCK NUT
COMMUTATOR SPRING
COMMUTATOR ROLLER ARM
FIBRE BED

Figure 100.—The Ford Model T timer

which holds the roller firmly against the metal segments. The timer is mounted at the front of the engine and the timer brush is driven from the front end of the camshaft gear. The spark is advanced and retarded by rotating the timer through a small angle, which is accomplished by moving the lever under the steering wheel. The spark timing may be varied within certain limits by lengthening or shortening the pull rod connected to the timer, and this is done by straightening or bending the rod.

COMMUTATOR

1709. The surface of the commutator on which the brush rolls should be clean and smooth. If the roller fails to make good contact on any one of the four contact segments, the corresponding cylinder will miss. These surfaces should be cleaned, if dirty, and if the fiber, contact points, or roller are badly worn, new parts should be substituted. These parts may be purchased so cheaply that it does not pay to try to repair them. The brush spring must be strong enough to make a good contact between the roller and the contact segments.

1710. The commutator should be lubricated once a week with a few drops of a mixture of kerosene and cylinder oil, although cylinder oil alone may be used in warm weather. The kerosene, however, is essential in cold weather, otherwise the thickened oil may prevent the brush from making good contact.

1711. The commutator is removed as follows: Take out the cotter pin from the spark rod and detach rod from commutator. Loosen the cap screw which goes through the breather pipe on top of the timing gear cover. This will release the spring which holds the commutator case in place and this part can then be removed. To remove brush, unscrew lock-nut, withdraw steel brush cap and drive out the retaining pin. Then lift out brush. Do not turn engine over while timer brush is removed, otherwise re-timing will be necessary.

TROUBLE ANALYSIS

1712. When the Ford magneto is used to supply the two headlights the methods used in detecting any faults in the lighting system are similar to those described for One Lamp (paragraph 1255).

1713. Ford ignition troubles may be classified under the following heads:

(1) Loss of power.

(2) Missing.

(3) Difficult starting.

(4) Stalling.

1714. How to determine whether the trouble is in the ignition system or elsewhere is described under Engine Troubles, Chapter XIII.

LOSS OF POWER

1715. Loss of power accompanied by overheating may be due to a late spark. See that the spark advance mechanism is working properly. Move the spark lever back and forth, noting that the timer moves correspondingly. If the timer does not move as the lever is moved, look for looseness or breakage in some member of the linkage. If the rod which connects with the timer is not the correct length the spark may be out of time. Take the cover off the timer case, retard the spark lever and bring cylinder No. 1 up to top dead center at the end of its compression stroke, using the method described in paragraph 1166. The timer roller should be beginning to make contact with the metal segment leading to coil No. 1. A quicker and less accurate method of determining dead center is to turn the engine over slowly until the exhaust valve on cylinder No. 4 closes. The piston in cylinder No. 1 should then be approximately at the end of its compression stroke, provided that the clearance between No. 4 exhaust valve and push rod is about $1/64$ inch. The timing may be adjusted within certain limits by bending or straightening the spark advance rod connected to the timer.

1716. Any condition which will produce weak sparks at the plugs may result in loss of power, although this condition is likely to be accompanied by missing and hard starting. Damp, oil-soaked or rotted high-tension wiring, coils improperly adjusted, weak magnets, dirty or worn timer, short-circuits or grounds in the magneto coils, magneto magnets too far away from the coils due to badly worn rear main bearing, spark-plugs with points improperly adjusted, dirty or with defective porcelain insulators may cause loss of power either alone or in combination. These conditions, however, will generally cause hard starting, missing or stalling, and their diagnosis and cure will be treated in detail under these headings.

MISSING

1717. A missing cylinder may readily be found as follows: Remove the cover on the coil box, and with the engine running idly at a speed approximating 25 miles an hour on high gear, run the engine on one cylinder at a time by holding down the vibrators on the other three cylinders with the fingers. If the missing cylinder is not firing at all, the engine will stall when run on this cylinder. However, if the missing is intermittent in this cylinder it may fire irregularly. When the missing cylinder has been detected, remove the spark-plug and proceed as described in paragraph 1416. See that the timer wires are properly connected. If the spark-plug is all right, lift the coil belonging to this cylinder out of the box and examine the points; file and adjust them, if required. If the vibrator buzzes continuously while the engine is running, it indicates that there is a ground in the low-tension wire running from this coil to the timer, or perhaps within the timer. If battery ignition is used in addition to the magneto, with the switch connected to battery the buzzing will be continuous with the engine stopped. It should also be clear that if the ground is intermittent the miss will also be intermittent.

1718. If the cause of the missing is still undetermined, exchange the coil on the missing cylinder with the coil on one of the other cylinders. If the miss remains in the same cylinder, it indicates that the trouble is not in the coil, but if the miss shifts to the other cylinder it shows that the trouble is in the coil. If the trouble is not in the coil, examine the high-tension wire leading from the coil to this spark-plug. See that the porcelain terminal on the coil box is not broken or cracked and that the high-tension wire has perfect insulation. Moisture due either to a heavy rainstorm or careless washing of the car may collect on the spark-plug, the high-tension wire or the coil and cause missing in one or more cylinders, although frequently stalling of the engine will result. If the moisture affects only one cylinder, it is advisable to wipe off the porcelain of the spark-plug and the porcelain terminal on the coil, using a dry rag although a rag wet with alcohol is better. If the missing persists the high-tension wire or the coil must be damp. With only one cylinder missing the coil and wire may dry out if the engine is run for a time on the remaining cylinders. Inasmuch as it is impossible to determine definitely by examination whether a coil or high-tension wire is damp enough to cause missing, it must be concluded that dampness is the cause, if the car has been thoroughly wet and the trouble is not found elsewhere, as described. If the trouble is still unlocated the timer should be treated as described in paragraph 1709.

1719. Excessive sparking at the vibrator points coupled with a weak spark or no spark at the spark-plug, indicates a defective condenser, and as it does not pay to repair a condenser, the coil should be discarded for a new one.

1720. If the trouble is not due to moisture the coil should be replaced with a new one; but if moisture is suspected, the coil should be placed in a warm spot, as on top of a steam radiator. If the coil is put in an oven, great care should be used to see that the temperature does not rise beyond 200° Fahrenheit, or the coil is likely to be damaged. Where an occasional coil is to be tested, the primary winding may be connected to a 6-volt storage battery and a ¼-inch spark-gap connected to the high-tension winding. If the spark jumps the gap the coil is satisfactory.

DIFFICULT STARTING

1721. If the engine starts reluctantly and misses after starting, the trouble may be due to moisture, under the conditions already described. Other causes of hard starting include dirty or worn timer parts, spark plug points too far apart, dirty spark-plugs, vibrators in need of adjustment, poor contact at magneto terminal, weak magnets, magnets more than 1/32 inch from coils due to worn rear main bearing cap, and grounds in magneto coils. Disconnect a high-tension wire at a spark-plug and hold it about 1/8 inch from the cylinder block while the engine is turned rapidly. If a full, regular spark is obtained it is likely that the hard starting is due to spark-plug points too far apart, dirty spark-plugs, or that the difficulty is not in the ignition system. The spark-plug points should be 1/32 inch apart. If only one man is available for this test, remove a spark-plug and connect it to its high-tension wire, then place it on the cylinder block in such a position that the points can be seen while the engine is cranked, being careful, however, to keep the spark-plug terminal far enough away from the engine so that the current will not jump from the terminal to ground. When the engine is cranked, a hot spark should appear regularly at the plug points. Still another method is to use a screwdriver with a wooden handle, grounding the point of the screwdriver on the engine and holding the shaft of the screwdriver about 1/4 inch from the spark-plug terminal while the engine is cranked rapidly. If a full spark jumps regularly between the spark-plug terminal and the screwdriver it is fairly good evidence that the trouble is either in the spark-plugs or not in the ignition system.

1722. If the spark is weak or irregular it is next necessary to determine whether the trouble is within the magneto or elsewhere in the ignition system. This is a simple matter if the car is equipped with dry cells or a storage battery. If the trouble is in the magneto, the engine should start readily when the ignition switch is on battery, provided that the dry cells or storage battery is in fairly good condition. If the engine starts just as reluctantly on the battery it indicates that all vibrators require adjusting, the timer is dirty or badly worn, or that moisture has affected the coils, high-tension wiring or spark-plugs. The insulation on the high-tension wiring may occasionally be sufficiently rotted so that hard starting is caused by excessive leakage of current from these wires; if so new wiring should be installed. If the car is not equipped with dry cells or battery, it is often advisable to connect one temporarily to determine whether the magneto is at fault.

1723. If the trouble is not in the magneto, the timer should be examined. Remove all dirt by wiping the interior with a rag well moistened with kerosene. Then lubricate with cylinder oil or a mixture of cylinder oil and kerosene. If the commutator brush spring is weak it should be replaced, and any other badly worn commutator parts should be replaced. Smooth and adjust any vibrators needing attention. Excessive tension on vibrators will cause hard starting. If the car has been exposed to a heavy rainstorm or careless washing within two or three days, and therefore starts reluctantly, the trouble will usually disappear after the car has been run long enough to dry out the parts due to the heat generated by the engine.

MAGNETO TROUBLES

1724. If the trouble is within the magneto the first point to examine is the magneto terminal, on the top of the flywheel housing. Under the terminal is a contact spring and brush connecting with the coils on the magneto. If dirt collects under this spring hard starting may result. The remedy is to remove the terminal, remove the spring and thoroughly clean the point directly underneath. Then replace spring and terminal. If it is known that the transmission band lining used in the car in question is not the standard Ford lining but a lining with brass wire in it (most if not all asbestos linings have brass wire); and further, if it is known that the lining has been in use for some time, it is possible that some pieces of wire in the lining have detached themselves and collected at the brush, thereby grounding it. Whenever this trouble is suspected the brush should be removed carefully by turning each of the three screws, holding the terminal flange, a little at a time. As this is done the brush spring will force the terminal up. Continue turning the screws until they are removed. Then carefully lift the brush out, when the pieces of wire will usually come out with the brush. If the coils are examined through the hole into which the brush fits, it may be found that pieces of brass wire are lying on the coils, causing grounds. These bits of wire should be removed carefully.

1725. If the trouble persists, the magnets are weak; the magneto coils are short-circuited or grounded; or the magnets are too far away from the coils, due to a worn rear main bearing. It must be explained here that the coils of the magneto are connected by a flat-copper ribbon which is not insulated. These ribbons are far enough away from the coil frame so that there is no danger of a ground as long as no dirt accumulates. These coils, of course, are bathed in engine oil whenever the engine is operating, and dirty engine oil is sure to contain more or less carbon particles and metallic particles, both of which are conductors of electricity. In time, these particles collect on the coil ribbons, and eventually cause grounds, with resultant hard starting, missing or loss of power. This condition may be largely prevented by draining the engine oil frequently, at least every 1,000 miles.

1726. If the car has a starter it is permissible to run on the battery indefinitely. There are two methods available for curing weak magnets or grounded coils. The older method requires that the engine be removed from the car, and completely disassembled, the old magnets removed and thrown away and the coil ribbons cleaned, or replaced if necessary. The newer method is to use the magneto coils to recharge the permanent magnets by sending a heavy current through the coils from two to four storage batteries connected in series with them. The current is also heavy enough to burn off the dirt which is grounding the coil ribbons. It has been amply demonstrated that the success of this method depends on the exactness with which the work is done, particularly in the position of the permanent magnets with reference to the magneto coils. The magnets can be recharged and the coil ribbons cleaned in a few minutes, whereas hours are required by the older method. The new method has really been known for years, but in the past the results obtained by it have been uncertain, but the method is now sufficiently well understood so that a perfect job is obtained in at least nine cases out of ten—the tenth case is explained presently. A number of Ford service stations, as well as many electrical repairmen, and general repairmen are using this method.

1727. Sometimes the method is not successful, but little is lost in using it. If occasionally the method fails, only a few minutes' time have been lost and a small amount of current. In this case the engine must be taken apart and new magnets installed, etc. Sometimes the magnets will not retain their magnetism and lose strength soon after being charged; sometimes the heavy current will burn out some of the coils on the magneto, which means that the engine must be torn apart and new coils put in. However, if the method were not used the engine would have to be torn apart in any case, so even in this event all that is lost is a little time, a little current, and perhaps the price of a new set of coils, which is small.

STALLING

1728. If the engine stalls and tests show that the trouble is in the ignition system, first note whether there is a battery in addition to the magneto. If there is a battery, place ignition switch on battery and crank engine. If vibrators buzz one by one both the low-tension and high-tension circuits are probably all right; in which case look for wet wires, fouled spark-plugs, or timer disconnected from its advance mechanism. Also be sure the trouble is not outside of the ignition system. If there is no battery, crank the engine vigorously by hand, noting if the various vibrators buzz regularly. If so, proceed as above. If vibrators fail to buzz, look particularly for ground or loose connection in wire running from magneto to coil, and also look for ground in wires running to light switch and horn (Figure 97), and if the trouble is still not determined, go over the ignition system thoroughly as described under Hard Starting, paragraph 1721.

CHAPTER XV

THE CLUTCH

1801. Clutches in recent years are limited to two broad types, the cone clutch (Figure 27), and the disc or plate clutch (Figures 101 to 108, inclusive). Strictly speaking, the terms disc and plate ar synonymous as applied to clutches, but common usage makes this distinction: A plate has a much larger diameter than a disc, and usually a plate clutch has only one, or two or three discs, whereas a disc clutch seldom has less than ten discs. Clutches which do not run in oil are called dry. Cone clutches are usually faced with leather; disc or plate clutches use specially treated asbestos fabric unless the clutch runs in oil, in which case the facing is sometimes omitted, as on the Ford Model T. The facing is attached by rivets, the facing bearing against metal.

1802. In the single-plate clutch a circular disc about a foot in diameter is attached to the shaft running to the transmission, and when the clutch is engaged this disc is clamped to the flywheel, being held firmly in place by one or more powerful clutch springs.

1803. In the multiple-disc clutch a number of discs are slidably mounted on a hub attached to the shaft running to the transmission. Sandwiched between them is another set of discs which are mounted on the flywheel shaft (Figure 104). The clutch spring or springs press all these discs together and the clutch rotates just as though it were a solid piece, while pressing down on the clutch pedal releases the clutch spring pressure with the result that the driving discs are no longer able to drive the driven discs, and the clutch is released or out.

1804. Some clutches are designed in such a way that when the clutch is fully disengaged, the driven member binds against some stationary part, thus "braking" the driven member and bringing it quickly to rest. This action facilitates gear shifting.

ADJUSTMENT

1805. The clutch facing gradually wears with the result that after 5,000 to 25,000 miles an adjustment is often required. Although it should be noted that some clutches have no adjustment, and are designed to operate satisfactorily until the lining is completely worn out and must be replaced. On most clutches the need for adjustment is indicated by the clutch pedal coming so close to the floor board that it almost touches. If there is an easy adjustment on the clutch pedal linkage, taking up on this adjustment sufficiently to bring the pedal ½ inch to 1 inch from the floor board is usually all the adjustment required.

1806. It should be emphasized that it is generally advisable to have your repairman adjust a clutch, but if you attempt to do it, the directions given in this chapter will serve as a guide.

1807. However, before making the adjustment it is advisable to inspect the clutch itself. If there seems to be an adjustment, and lacking specific information as to the method, adjust clutch until clutch pedal is drawn ½ to 1 inch from the floor board. But regardless of this rule the clutch should be adjusted so that it does not slip on the one hand, nor fail to release fully on the other. If when this clutch adjustment is obtained, if pedal does not stand ½ inch to 1 inch from floor board, adjust clutch pedal linkage it until it does. If a clutch pedal is built to lie close to the floor board and is held there by a spring, adjust clutch, clutch pedal or both (as the case may be) until about 1-inch pedal travel is required before the clutch begins to release.

1808. In adjusting the clutch note carefully whether there is only one or more than one adjusting screw. If more than one all should be adjusted equally.

1809. Most clutch facings require no lubricant. There are, however, a few cars with clutches designed to run in cylinder oil or a half and half mixture of kerosene and cylinder oil. When in doubt, it is advisable to obtain information on this point from a dealer selling your make of car.

LUBRICATION

1810. Some clutch bearings require special lubrication and some do not, being oiled automatically from the engine. The lubrication of these bearings is extremely important and it is advisable to obtain definite information on this point from your instruction book, from a dealer who sells the make you have, or from your repairman.

1811. As a rule, an examination of the clutch and housing will reveal the points requiring lubrication, but not always.

CLUTCH TROUBLES

1812. Clutch troubles may be grouped under the following heads: Slipping, dragging, spinning, and grabbing. Slipping is indicated by the engine running faster than normal at any given car speed, and in an extreme case regardless of how slow or fast the engine is run the car fails to move, or slipping may be observed when starting up, when the throttle is opened wide to give maximum acceleration. It is also frequently first noted when climbing a steep hill on high gear, when the engine may suddenly increase its speed without any increase in car speed.

1813. Slipping wears the clutch rapidly, and once slipping occurs, unless care is used, it may soon be impossible to run the car, due to excessive clutch wear. If the various remedies for slipping (paragraph 1819), prove unavailing, or if the driver does not wish to try these cures, he should drive to minimize slipping. This means starting slowly, and particularly, shifting to a lower gear when slipping occurs. In other words, if slipping occurs on high immediately shift to second, and if slipping takes place on second shift to low. On any of these gears, and low especially, slipping may be minimized by running with as small a throttle opening as possible, and when it is necessary to open the throttle do so gently.

1814. Dragging is indicated by failure of the clutch to release fully, the driving member dragging the driven member along with it even when the clutch pedal is pushed all the way out. This trouble may first make itself felt by clashing of the gears when going from neutral into low gear when starting the car, although before assuming that this is the trouble be sure that you do not fail to push the clutch pedal out all the way (necessary on some cars).

1815. Spinning may be defined as failure of the driven member of the clutch to come to rest quickly when the clutch pedal is depressed all the way. It causes difficulty in starting, the same as does dragging.

1816. In the case of both spinning and dragging, more or less difficulty may be experienced in all gearshifting.

1817. Grabbing describes a tendency of the clutch to take hold too suddenly with the result that great skill is required to start the car to prevent stalling the engine on the one hand, and to prevent spinning the rear wheels on the other. Grabbing clutches are responsible for a great deal of rear-axle trouble.

1818. If the grabbing can not be cured, as described in paragraph 1838, and difficulty is experienced in starting smoothly; a smoother start may be obtained by starting in second. The clutch facing is worn a little more by so doing, but the rear axle and tires are strained less.

SLIPPING

1819. Symptom—Clutch slips.

1820. Causes—(1) Too much oil on clutch surfaces. (2) Clutch needs adjusting. (3) Clutch springs weak. (4) Clutch badly worn.

1821. Cure—1. When a clutch slips, the first step is to wash it with gasoline. If the clutch runs in oil drain the chamber, put in a quart or so of gasoline, and crank the engine for about one minute on the starter, meanwhile moving the clutch in and out of engagement continuously. Then refill with cylinder oil or a mixture of cylinder oil and kerosene, as required, see paragraph 1809. If clutch continues to slip, see Cures 2, 3, and 4.

1822. If the clutch is a dry-cone type, obtain some fuller's earth at a drug store and sprinkle it on the clutch facing. To do this, remove the floor boards, and hold the clutch out, and shovel the fuller's earth on to the facing, using a piece of thin card board. Turn the clutch by hand after each application so that the whole clutch surface is rather evenly covered. Then if the clutch grabs, squirt a few drops of neat's foot oil on the surface. This may also be obtained at a drug store. In an emergency, if fuller's earth is not available, use any powder such as talcum. Use fine sand or dirt only when forced to do so, and then wash the sand out with gasoline at the first opportunity. If clutch continues to slip, see Cures 2, 3, and 4.

1823. If the clutch is a dry plate or dry disc, wash with gasoline. If the clutch is in a chamber, plug the drain hole in the bottom, and pour in a quart or so of gasoline. Run the engine on the starter for one minute, working the clutch in and out continuously. Then drain the chamber. If the clutch continues to slip sprinkle with fuller's earth while the clutch is disengaged. If slipping is not eliminated, see Cures 2, 3, and 4.

1824. If the clutch is not in a chamber, squirt gasoline over it with an oil gun or pour gasoline over it slowly, working the clutch in and out while the engine rotates slowly. For safety, do this work out of doors.

1825. Cure—2. The clutch may require adjusting after the first few hundred miles to compensate for initial wear of the lining, but after that, clutch adjustment is not likely to be required within 5,000 to 25,000 miles, depending on the clutch and the care it receives. Wear of the lining is caused almost entirely by excessive slipping in starting and driving in traffic.

1826. If Cure 1 fails to stop slipping, the clutch should be adjusted, see paragraph 1805.

1827. Cures—3 and 4. If Cures 1 and 2 do not eliminate slipping, the trouble must be due to weak clutch springs or worn lining, and the work from this point on should be done by your repairman.

DRAGGING

1828. Symptom—Clutch drags.

1829. Causes—(1) Clutch adjusted too tightly. (2) Rivets sticking out in facing. (3) Clutch bearing worn or broken. (4) Clutch out of alinement.

1830. Cure—1. Reduce clutch adjustment just enough to cure dragging but not enough to cause slipping. See paragraph 1805 for clutch adjustment.

1831. Cure—2. If clutch facing is badly worn rivets may stick out and cause dragging, in which case, new lining should be installed. If clutch has just been refaced and rivets have not been countersunk, the same trouble may be experienced.

1832. Cure—3. A worn clutch bearing may also be noisy, and if very badly worn or broken, gear engagement may be almost impossible. Consult your repairman.

1833. Cure—4. Consult your repairman.

SPINNING

1834. Symptom—Clutch spins.

1835. Causes—(1) Oil on clutch brake. (2) Clutch adjusted too tightly.

1836. Cure—1. Wash clutch brake with gasoline. If you can not find clutch brake, wash the whole clutch mechanism with gasoline.

1837. Cure—2. Reduce clutch adjustment.

GRABBING

1838. Symptom—Clutch grabs.

1839. Causes—(1) Gummed oil on clutch surfaces. (2) Adjustment too tight. (3) Rivets sticking out from clutch facing. (4) Lining glazed.

1840. Cure—1. Wash clutch as described under slipping, paragraph 1819. If clutch is a leather-faced cone running dry, squirt neat's foot oil on the leather.

1841. Cure—2. The adjustment is likely to be too tight only if clutch has recently been adjusted. In this case, reduce adjustment; otherwise see Cures 1, 3, and 4.

1842. Cure—3. If clutch facing is badly worn, rivets may stick out, in which case refacing is required. Consult your repairman. If clutch has recently been refaced and rivets were not countersunk properly, they may also cause grabbing. In the latter case, if grabbing does not stop after rivets are worn down, the job must be done over.

1843. Cure—4. Wash with gasoline, see paragraph 1821, and if this does not cure the trouble, consult your repairman.

NOISY

1844. Symptom—Clutch noisy.

1845. Causes—Various.

1846. Cure—If proper lubrication of clutch mechanism does not cure the noise, consult your repairman. Noise that appears to come from the clutch may actually be due to some defect in engine; transmission, or front universal joint.

WEAK PEDAL ACTION

1847. Symptom—Weak pedal action.

1848. Cause—(1) Broken or disconnected clutch riding spring.

1849. Cause—(2) Broken or weak clutch springs.

1850. Cure—1. Some cars are fitted with a heavy spring on the clutch pedal, designed not only to hold the pedal up but also to take the weight of the foot when it is rested idly on the clutch. If the clutch does not slip, look for a broken or disconnected clutch riding spring. The spring should be replaced when convenient.

1851. Cure—2. Weak or broken springs within the clutch may cause weak clutch pedal action, and probably will also cause clutch slipping. See other causes of slipping, paragraph 1819. Have the defect repaired as soon as possible.

CHATTERING

1852. Symptom—Clutch chatters.

1853. Causes—Various.

1854. Cure—Wash with gasoline as described in paragraph 1821. Otherwise consult your repairman.

CLUTCH ADJUSTMENTS ON VARIOUS CARS

1855. Specific directions for adjusting the clutches on various popular cars are given in the following pages. The adjustments are typical and therefore should serve as a guide in adjusting the clutches on cars not mentioned.

CHEVROLET

1856. The pedal on the Chevrolet clutch (Figure 101), must be kept at least ¾ inch from the end of the slot in the floor board, and must be perfectly free from interference or rubbing on the sides of the opening or slot in the floor boards. As the clutch collar and clutch parts gradually wear, the clutch pedal will move backward gradually toward the floor boards. Ad-

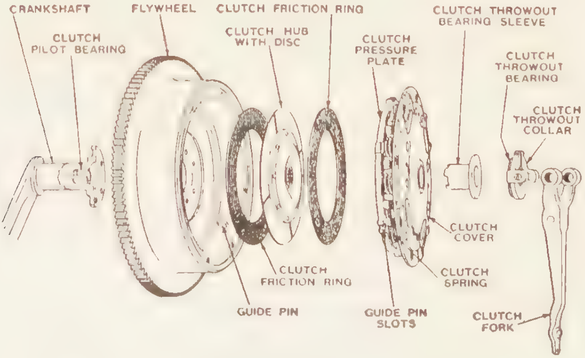

CRANKSHAFT
FLYWHEEL
CLUTCH FRICTION RING
CLUTCH THROWOUT BEARING SLEEVE
CLUTCH PILOT BEARING
CLUTCH HUB WITH DISC
CLUTCH PRESSURE PLATE
CLUTCH THROWOUT BEARING
CLUTCH THROWOUT COLLAR
CLUTCH COVER
CLUTCH FRICTION RING
CLUTCH SPRING
GUIDE PIN
GUIDE PIN SLOTS
CLUTCH FORK

Figure 101.—Details of clutch in Chevrolet car

ditional adjustment may be secured by changing the position of the clutch pedal stop. Loosen the cap screw which clamps the stop to the cylinder block and change the angularity of the stop by either raising or lowering. Then tighten the cap screw in the stop slot. This operation increases or decreases the throw of the pedal.

DODGE SENIOR SIX

1857. The clutch on the Dodge Senior six is adjustable for wear (Figure 102), by turning the cover on the flywheel. There is a stop screw which limits the travel of the clutch pedal. The adjustment of this screw is made at the factory and should not be tampered with. Adjustment for wear should always be made by turning the cover.

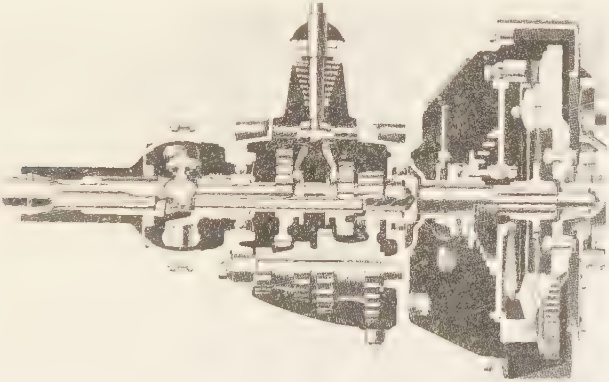


Figure 102.—Dodge "Senior Six" clutch, transmission, and universal joint

CHRYSLER IMPERIAL EIGHTY

1858. Figure 103 illustrates the parts of the clutch assembly in the Chrysler Imperial 80, and should be referred to in connection with these instructions. The release bearing and pedal must be in their proper positions. This is accomplished by setting the release shaft lever stop screw, No. 55,820, so that the rear face of the release bearing sleeve, No. 55,415, is exactly 5/16 inch forward of the front face of the adjacent shoulder on the release sleeve support– that is, the release bearing sleeve should be 5/16 inch forward from its rear stop. Then the release fork, No. 55,862, should be adjusted to set the pedal as high as possible without interference with the floor board after the release bearing and pedal are in proper relation and engaged position. Next, the three release levers, No. 55,414, should be adjusted to 3/16-inch clearance at the release bearing. The clutch pedal should have from 1 1/4 to 2 inch of free movement before any resistance can be felt.

1859. Important—Owing to the compound leverage arrangement employed in the clutch pedal hook-up to reduce the effort required for operation, the slight amount of play prevailing in the two pins, connecting the release link, No. 50,595, to the levers, results in as much as 1 inch of free movement of the clutch pedal and is often mistaken for proper pedal adjustment when the release fork, No. 55,862, inside the housing is actually riding the release bearing, resulting in slight slippage, which soon becomes excessive, causing failure of the woven facing. The adjustment at linkage positively has no connection with the free movement of the clutch pedal, but is only provided to adjust for clearance at toe board and to change the angle of the pedal.

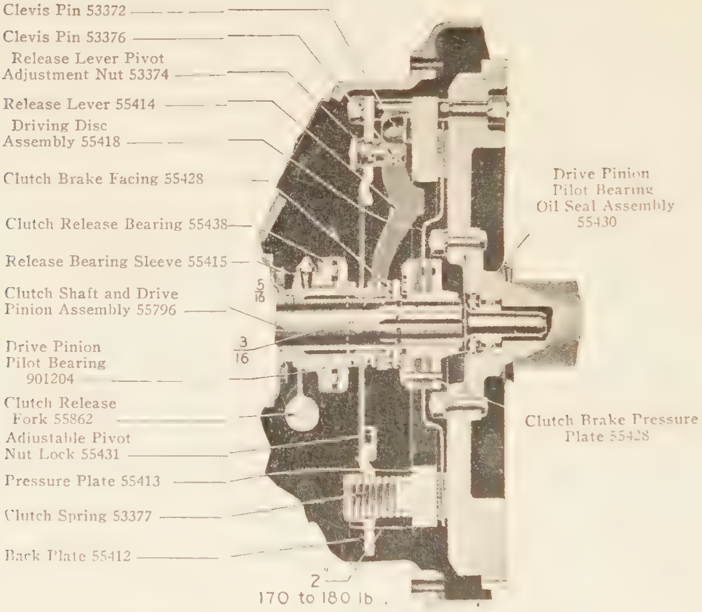

Clevis Pin 53372
Clevis Pin 53376
Release Lever Pivot Adjustment Nut 53374
Release Lever 55414
Driving Disc Assembly 55418
Clutch Brake Facing 55428
Clutch Release Bearing 55438
Release Bearing Sleeve 55415
Clutch Shaft and Drive Pinion Assembly 55796
Drive Pinion Pilot Bearing 901204
Clutch Release Fork 55862
Adjustable Pivot Nut Lock 55431
Pressure Plate 55413
Clutch Spring 53377
Back Plate 55412
5/16
3/16
2"
170 to 180 lb.
Drive Pinion Pilot Bearing Oil Seal Assembly 55430
Clutch Brake Pressure Plate 55428

Figure 103.—Details of clutch in Chrysler 80 car

1860. The clutch release-shaft lever stop screw, No. 55,820, controls the free movement between release bearing and fork. It is imperative, therefore, to distinguish the difference between these two adjustments. The release levers are individually adjustable by turning the adjacent pivot-adjusting nut, No. 53,374. Anti clockwise turning of the adjusting nuts increases the clearance between release bearing and release levers and compensates for wear of frictional members.

1861. In this connection, it is well to warn drivers against the practice of resting the foot on the clutch pedal while driving. The weight of the foot holds the clutch throw-out yoke against the release bearing, with consequent rapid wear and noise; reduces tension of the clutch springs, causing slippage and loss of power; causes rapid wear of the facings, producing sluggish clutch action, rattles and knocks. The practice of resting the foot on the clutch pedal will necessitate more frequent lubrication. The clutch-shaft bearing in the crankshaft is of the annular ball type and requires no attention except that it is good practice to pack it with a good fiber grease when ever the clutch is removed from the car. The roller bearing at the rear of the clutch shaft receives its lubrication from the transmission.

FORD MODEL T MULTIPLE DISC

1862. The Ford Model T clutch is engaged only on high gear. To adjust, remove the hand-hole cover on top of the transmission, place the hand brake in neutral, jack up one rear wheel and rotate it until one of the clutch finger adjusting screws (Figure 104), comes into view. Remove the cotter-pin, being careful not to drop it into the transmission, and give this screw one-half turn inward. Rotate the clutch one-third revolution by turning the rear wheel, and adjust the next screw similarly. Rotate another third of a revolution and adjust the third screw. Some screws will have to be adjusted more than half a turn. Be sure to put the cotter-pins back and spread them carefully. If the discs are badly worn, adjustment may not be sufficient; then new discs will be required. If the clutch drags, it is adjusted too tightly or the clutch lever screw (Figure 45), requires adjusting, the latter being the

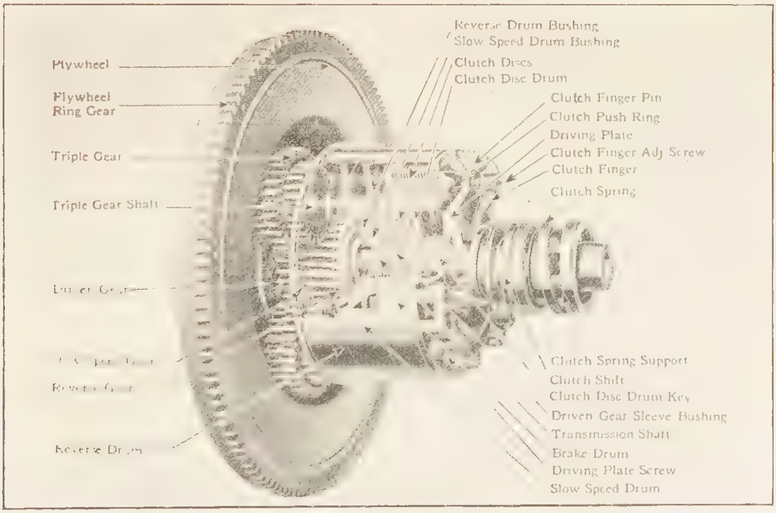

Flywheel
Flywheel Ring Gear
Triple Gear
Triple Gear Shaft
Driven Gear
Slow Speed Gear
Reverse Gear
Reverse Drum
Reverse Drum Bushing
Slow Speed Drum Bushing
Clutch Discs
Clutch Disc Drum
Clutch Finger Pin
Clutch Push Ring
Driving Plate
Clutch Finger Adj Screw
Clutch Finger
Clutch Spring
Clutch Spring Support
Clutch Shift
Clutch Disc Drum Key
Driven Gear Sleeve Bushing
Transmission Shaft
Brake Drum
Driving Plate Screw
Slow Speed Drum

Figure 104.—Ford Model T clutch and transmission

case if the clutch has not recently been adjusted too tightly. Dragging in this case is usually indicated by creeping of the car while being cranked with hand brake off. Release the lock-nut and turn the clutch lever a half-turn inward, and more if necessary. Be sure to tighten the lock-nut. If the clutch drags, the engine oil may be too thick, or some dragging may be noted in any case in very cold weather, probably accompanied by hard cranking.

FRANKLIN

1863. The clutch (Figure 105), must be adjusted so that there is about $\frac{1}{16}$-inch clearance between the throw-out bearing *F*, and the puller yoke *G*, which is equivalent to $\frac{1}{2}$-inch free motion in the clutch pedal. When this clearance is taken up, due to natural wear in the friction rings, readjustment is required; otherwise, the clutch will slip. The clutch is adjusted by moving the adjusting ring clockwise to compensate for wear. To release the adjusting ring, pull out the locking pin *E*, and turn it downward to hold it in position. Insert a screwdriver through the clutch cover, release the clutch, turn the rings one or more notches as required, then replace locking pin. This is only adjustment ordinarily required.

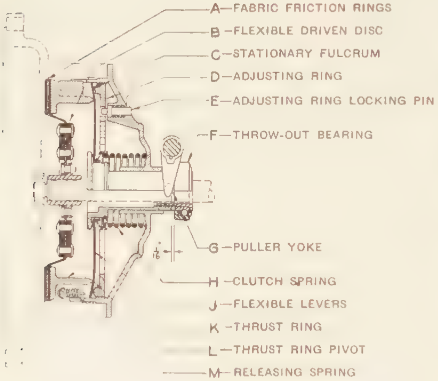

A—FABRIC FRICTION RINGS
B—FLEXIBLE DRIVEN DISC
C—STATIONARY FULCRUM
D—ADJUSTING RING
E—ADJUSTING RING LOCKING PIN
F—THROW-OUT BEARING
G—PULLER YOKE
H—CLUTCH SPRING
J—FLEXIBLE LEVERS
K—THRUST RING
L—THRUST RING PIVOT
M—RELEASING SPRING

Figure 105

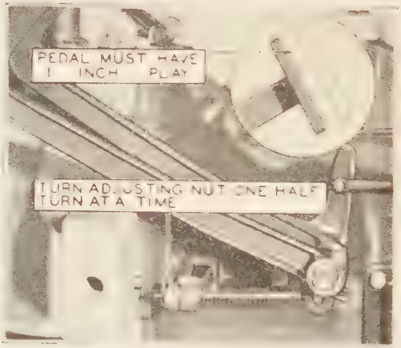

PEDAL MUST HAVE 1 INCH PLAY
TURN ADJUSTING NUT ONE HALF TURN AT A TIME

Figure 106

Figure 105.—Details of clutch in Franklin car

Figure 106.—Details of clutch in La Salle car

LASALLE

1864. The clutch pedal in the LaSalle car (Figure 106), is purposely given about 1 inch of "lost motion"—that is to say, the clutch does not begin to disengage until the pedal has been moved down about an inch from its released position. This lost motion is necessary to allow the clutch discs and plates to come closer together as the facings are reduced in thickness. The lost motion gradually decreases as the clutch is used, and eventually will be taken up. Before this happens, the clutch release rod must be readjusted to restore the lost motion; otherwise the clutch discs will slip and the engine will not drive the car. To make the adjustment, unscrew the nut on the end of the rod until the clutch pedal has a movement of 1 inch without starting to disengage the clutch. The nut must be turned a half-turn at a time.

STUTZ

1865. When the Stutz clutch (Figure 107), is properly adjusted, the distance from the rear wearing surface of the release sleeve to the clutch cover should be $2\frac{7}{16}$ inches. After the clutch has been properly adjusted at the factory the clutch pedal is adjusted for ½ inch of free motion. Adjustment at the lower end of the clutch pedal should not be used as a means of compensating for clutch wear. To adjust the clutch, loosen the three cap screws which hold the clutch cover in place on the flywheel. Turning the clutch cover clockwise while looking toward the front of the car tightens the clutch spring and decreases the distance from the rear wearing surface of the release sleeve to the clutch cover. This also increases the amount of free travel of the clutch pedal and compensates for any wear on the friction facings. After turning the clutch cover, tighten the three cap screws which hold the cover in the flywheel before checking the adjustment.

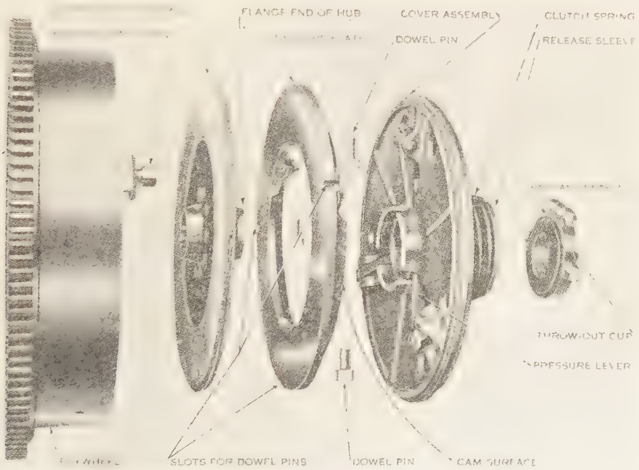


Figure 107.—Details of clutch in Stutz car

Chapter XVI

THE TRANSMISSION

TROUBLES

1901. Transmission troubles are few, and those that do occur generally require the services of an experienced man, because the remedy ordinarily involves the replacement of some parts. On passenger cars the main shaft is usually mounted on ball or non-adjustable roller bearings, although in some cars, taper roller bearings are used, the latter being adjustable for wear. The drive-gear inner bearing generally called the spigot bearing, is mostly a plain bearing, although ball or roller bearings are used to some extent. In some cars the countershaft gears are attached firmly to a countershaft, which is mounted in a bearing at either end, and in others, the countershaft is fastened to the transmission case and the gears rotate upon it, the hubs of the gears are bushed, as a rule, although roller bearings are sometimes used.

1902. As described in paragraph 64, the gears on the main shaft are slidably mounted and are shifted by forks attached to shifting rods which are moved by the gear-shift lever. The fork moving high and second gear is attached to one rod and the fork moving low and reverse to another rod. Each rod is locked automatically in three positions—high, neutral, second; and low, neutral, reverse. Locking is ordinarily accomplished by cutting three notches in each rod and allowing a plunger or ball, backed by a suitable spring, to press itself into one of the notches. The notches on each rod are so spaced that when high gear is engaged the plunger or ball rests in the high-gear notch, and similarly for the neutral notch and the second gear notch, as well as for low, neutral, and reverse notches on the other rod.

NOISE

1903. Symptom—Excessive noise.

1904. Causes—(1) Lack of lubricant. (2) Worn, bent or loose parts.

1905. Cure—1. Fill with heavy transmission oil up to level of plug or filler opening in the side of transmission case. If there is no side filler plug, remove plug or cover in the top of the case and fill up to center of countershaft. Lack of lubricant is less likely to damage the transmission than the rear axle, provided that most driving is done on high gear. Do not use grease.

1906. Cure—2. Worn gears or bearings, bent shafts or loose parts anywhere in the transmission may cause excessive noise. If lubrication fails to minimize the noise, consult your repairman. Worn gears or bearings are not likely to cause any trouble until they become so badly worn that breakage occurs.

GEAR SLIPS OUT

1907. Symptom—Gear slips out.

1908. Causes—(1) Shift lock at fault. (2) Badly worn gears, loose gears, or bent shaft.

1909. Cure—1. If a gear slips out occasionally, as after striking a severe bump, pay no attention to it, but if gears slip out habitually, look for the cause. The first place to look is the shift lock on the rod controlling the gear affected. See that the spring is not weak or broken and that the retaining nut or plunger is not loose or missing. See that plunger and notches are not too badly worn. Except for loose or missing parts, better leave the work to your repairman.

1910. Next, see that gear-shift lever moves the gear all the way into mesh. If not, tighten ball joint on gear-shift lever, and transmission cover, if required. If this does not remedy the trouble, note whether shifter fork is correctly placed. Determine this point by removing transmission cover, and shifting the fork by hand until the gear is locked in position. If the sides of the two meshing gears are flush the fork is all right, but if the gears are not flush by $\frac{1}{16}$ inch or so, and if the other gear controlled by this rod meshes plus or minus a like amount, adjust the shifter fork.

1911. Cure—2. If the shifting mechanism is in good shape but the gears are badly worn or chipped, or if the countershaft gears are wobbly on their shaft, or if main or countershafts are very loose in their bearings, or if these shafts are bent, the gears may fail to stay in mesh. Consult your repairman.

1912. If the car must be used while one or more gears slip out, the trouble may be minimized by running with the throttle closed as far as possible when in gear, and any remaining tendency to slip out may usually be counteracted by holding the gear lever in position by hand.

GEARS CLASH

1913. Symptom—Gears shift noisily (clash).

1914. Causes—1. Clutch drags or spins. 2. Main or countershaft bearings very loose.

1915. Cure—1. See paragraphs 1838 and 1834.

1916. Cure—2. In a few cases these bearings are adjustable; otherwise, consult your repairman.

TRANSMISSION KNOCKS

1917. Symptom—Transmission knocks.

1918. Causes—(1) Broken gear tooth. (2) Trouble elsewhere.

1919. Cure—1. A thump when in gear usually indicates a broken gear tooth. Have gear replaced as soon as possible.

1919A. Cure 2. Knocks which appear to come from the transmission usually are knocks transmitted from the engine or the universal just to the rear of the transmission. Supply grease to one or both universals (as the case may be) and carefully tighten all loose screws and nuts on the universals. For engine knocks, see paragraph 1575. See that transmission case is not loose where it is attached to frame or engine.

SHIFT LEVER VIBRATES

1920. Symptom—Gear-shift lever vibrates.

1921. Cause—Loose mounting.

1922. Cure—Tighten gear-shift lever mounting.

TRANSMISSION FAILS

1923. Symptom—Transmission fails to function.

1924. Causes—(1) Gear-shift lever broken or loose. (2) Gears stripped—teeth completely broken off.

1925. Cure—1. Examine gear-shift lever. If it is broken, continue your journey on high if in level country. If in moderately hilly country continue on second, making a permanent shift to one or the other of these gears, by operating the shifting rod by hand, if necessary remove the transmission cover to do this.

1926. Cure—2. This can not happen to all gears at once. It is advisable to remove transmission cover and fish out broken teeth to prevent further damage. The car may be operated on gears which are intact.

GEARS CAN NOT BE SHIFTED

1927. Symptom—Gears can not be shifted.

1928. Cause—Shifting mechanism defective.

1929. Cure—Remove cover from transmission and examine shifting mechanism. See that both shifting forks are in proper adjustment as described in paragraph 1909. If so, bring both shifting forks to neutral, put transmission cover back and try gear shifting. If trouble is cured, forget about it. If not cured, proceed home by shifting permanently to high or second according to whether the country is level or hilly. Do not make the mistake of meshing two sets of gears at the same time, or breakage is likely to occur.

FORD MODEL T TRANSMISSION

1930. The Ford Model T has a planetary transmission (Figures 45 and 104), whereas all other American cars have a sliding-gear transmission. It has two forward speeds and one reverse. High gear or direct drive is obtained by releasing the hand brake, while low gear is obtained by pressing on the left pedal, its initial movement disengaging the clutch (which gives direct drive on high gear). This pedal has a neutral position where neither high nor low are engaged, and as previously stated, this position may also be obtained by applying the hand brake. Reverse is obtained by pressing on the middle pedal with the right foot while the left pedal is held in neutral with the left foot. The right pedal operates the service brake.

1931. Nothing is gained by completely detailing the action of the Ford Model T transmission, but it should be sufficient to state that depressing the left pedal causes a band in the transmission to grasp a rotating drum. As long as the drum is held stationary by the band, low gear is engaged. Similarly, depressing the reverse pedal causes another band to grip its drum, and reverse is engaged as long as the drum is held stationary. The right pedal actuates a band which grips a third drum, but this is merely the transmission brake, and is no different in principle from any transmission brake.

BAND ADJUSTMENT

1932. If the bands do not grip properly, adjust them, and if they still fail to grip they should be relined. Relining is frequently required long before the lining is worn out, due to the glazing of the surface of the lining, which in turn reduces the gripping power and causes chattering. These troubles may be minimized by using a good engine oil and changing it every 500 miles, and here it should be noted that some engine oils made for the Ford are designed to minimize glazing and chattering.

1933. The low speed band may be tightened by loosening the lock-nut at the right side of the transmission cover (Figure 45), and turning the adjusting screw to the right. To tighten the brake and reverse bands remove the transmission cover door and turn the adjusting nuts on the shafts to the right. See that the bands do not drag on the drums when disengaged, as they exert a braking effect, and tend to overheat the motor. However, the foot brake should be adjusted so that a sudden pressure will stop the car immediately, or slide the rear wheels in case of emergency. The bands, when worn to such an extent that they will not take hold properly, should be relined.

1934. To reline the bands, remove them as follows: Remove the starting motor. Take off the door on top of transmission cover. Turn the reverse adjustment nut and brake adjustment nut to the extreme end of the pedal shafts, then remove the slow-speed adjusting screw. Remove the bolts holding the transmission cover to crankcase and lift off the cover assembly. Slip the band nearest the flywheel over the first of the triple gears, then turn the band around so that the opening is downward. The band can now be removed by lifting upward. The operation is more easily accomplished if the three sets of triple gears are so placed that one set is about 10 degrees to the right of center at top. Each band is removed by the same operation. It is necessary to shove each band forward on to the triple gears as at this point only is there sufficient clearance in the crankcase to allow the ears of the transmission bands to be turned downward. By reversing this operation the bands may be installed.

Chapter XVII

THE REAR AXLE

BEVEL-GEAR ADJUSTMENT

2001. If the bevel gears in the rear axle become noisy, supply them with lubricant as described in paragraph 212. If this fails to cure the trouble, adjustment of the gears is probably required. As a rule, it is advisable to have your repairman do this work, and the following information is only of interest if you wish to make the adjustment yourself.

2002. The rear-axle gearing has been described in paragraph 100, and the reader should review the principles of construction if they have been forgotten before reading further.

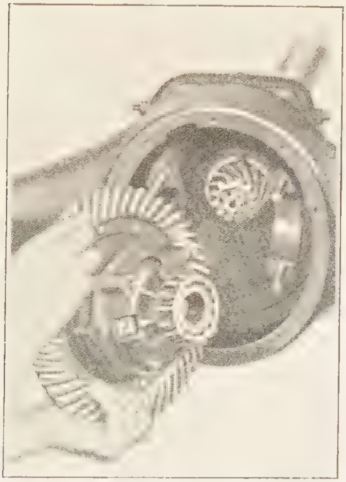


Figure 108

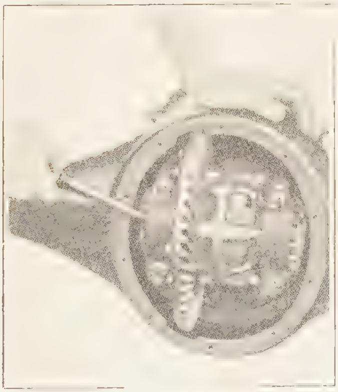


Figure 109

Figure 108.—Bevel pinion and ring-gear mechanism

Figure 109.—Method of mounting differential unit

2003. Figure 108 shows the differential mechanism and bevel gear (generally called ring gear) removed from the axle, while the bevel pinion is seen in the axle housing. The differential unit is mounted in two bearings which are held in place by clamps (Figure 109). The complete mechanism cut in two horizontally is shown in Figure 110, and is shown partly disassembled in Figure 111. Additional details regarding rear-axle construction are given in Figures 112 to 115 inclusive. The shaft which carries the bevel pinion is ordinarily mounted in two bearings, as shown in the various illustrations.

2004. Bevel pinion and ring gear must be properly meshed to insure quiet operation and to prevent undue wear. As time proceeds the mesh becomes looser, partly due to gear tooth wear and partly to bearing wear, and the resultant noise indicates that it is time for adjustment.

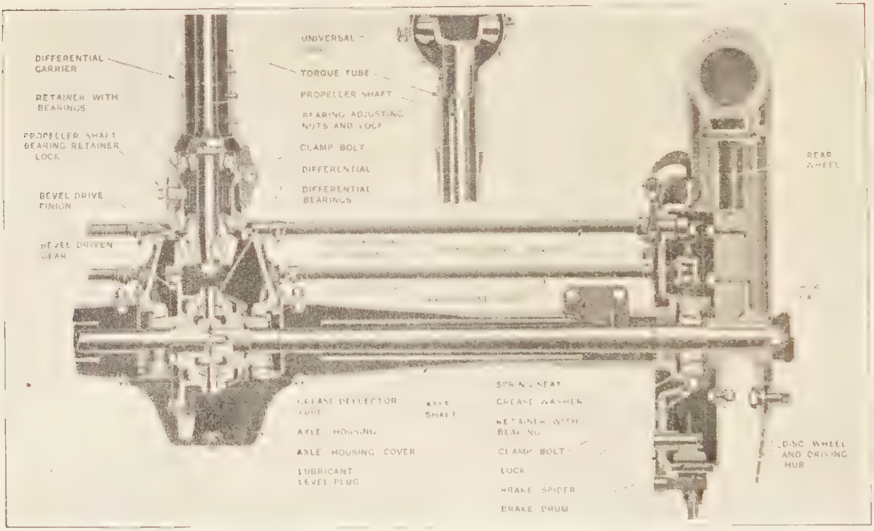

DIFFERENTIAL CARRIER
RETAINER WITH BEARINGS
PROPELLER SHAFT BEARING RETAINER LOCK
BEVEL DRIVE PINION
BEVEL DRIVEN GEAR
UNIVERSAL
TORQUE TUBE
PROPELLER SHAFT
BEARING ADJUSTING NUTS AND LOCK
CLAMP BOLT
DIFFERENTIAL
DIFFERENTIAL BEARINGS
REAR WHEEL
GREASE DEFLECTOR TUBE
AXLE SHAFT
AXLE HOUSING
AXLE HOUSING COVER
LUBRICANT LEVEL PLUG
SPRING SEAT
GREASE WASHER
RETAINER WITH BEARING
CLAMP BOLT
LOCK
BRAKE SPIDER
BRAKE DRUM
DISC WHEEL AND DRIVING HUB

Figure 110.—Rear axle cut in two horizontally

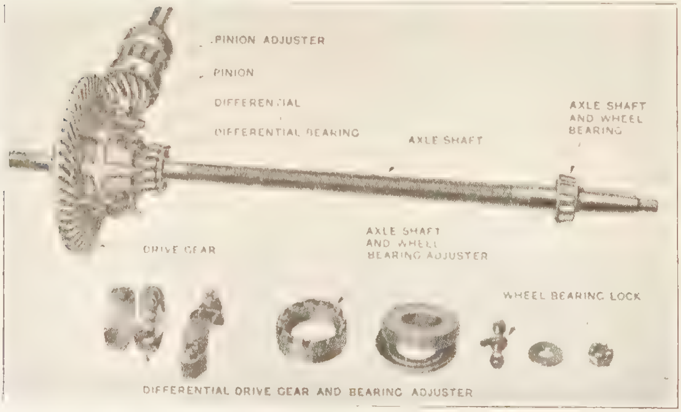

PINION ADJUSTER
PINION
DIFFERENTIAL
DIFFERENTIAL BEARING
AXLE SHAFT
AXLE SHAFT AND WHEEL BEARING
DRIVE GEAR
AXLE SHAFT AND WHEEL BEARING ADJUSTER
WHEEL BEARING LOCK
DIFFERENTIAL DRIVE GEAR AND BEARING ADJUSTER

Figure 111.—Bevel pinion, ring-gear and differential, axle shafts and bearings

2005. The gears may be considered correctly meshed when the outer edges of the teeth are flush, as shown in Figure 112, and when the back lash is about 0.007 inch, or approximately three times the thickness of this paper. Back lash is defined as the space or play between any two adjacent teeth. Inasmuch as it is not easy to measure the back lash, the gears may be considered in correct adjustment when the noise produced is a minimum.

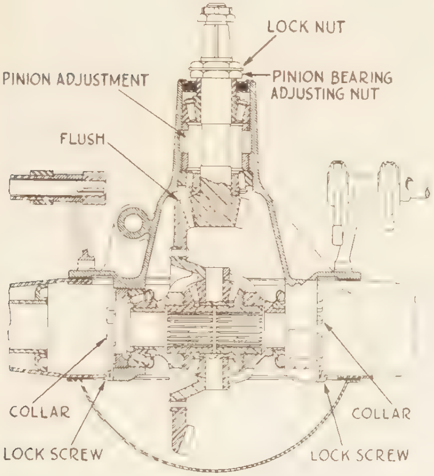

LOCK NUT
PINION ADJUSTMENT
PINION BEARING ADJUSTING NUT
FLUSH
COLLAR
LOCK SCREW
COLLAR
LOCK SCREW

Figure 112

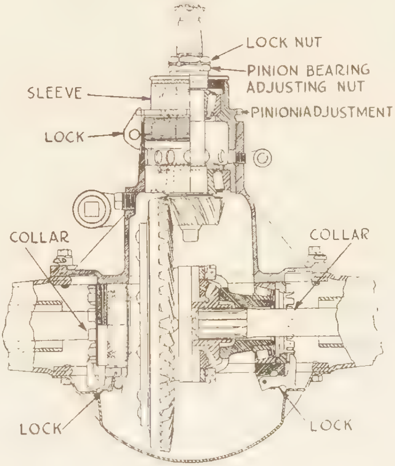

LOCK NUT
PINION BEARING ADJUSTING NUT
SLEEVE
PINIONIADJUSTMENT
LOCK
COLLAR
COLLAR
LOCK
LOCK

Figure 113

Figure 112.—Rear axle showing points of adjustment
Figure 113.—Rear axle showing points of adjustment

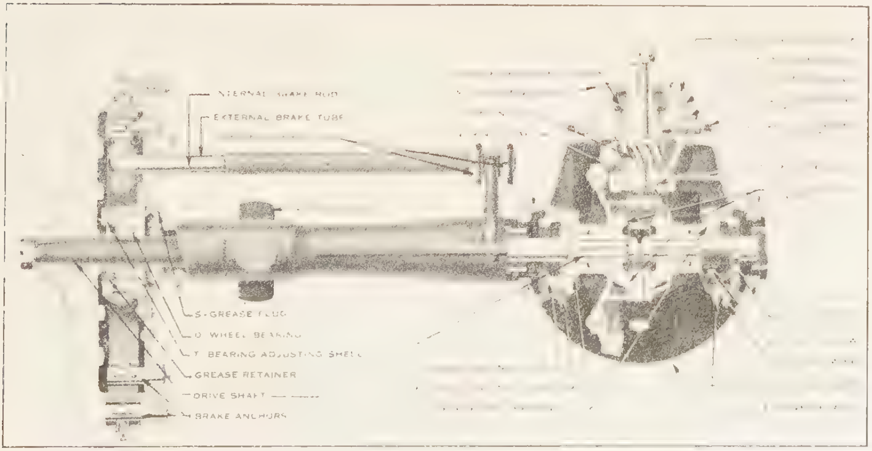

NTERNAL BRAKE ROD
EXTERNAL BRAKE TUBE
S-GREASE PLUG
D WHEEL BEARING
T BEARING ADJUSTING SHELL
GREASE RETAINER
DRIVE SHAFT
BRAKE ANCHORS

Figure 114.--Semi-floating rear axle showing adjustments

RING-GEAR ADJUSTMENT

2006. The ring gear may be adjusted to mesh more closely with the pinion by moving it toward the pinion (Figure 112). This is accomplished by turning the right collar in a counter-clockwise direction for a part of a revolution and then turning the left collar the same amount in the same direction, although note that sometimes the latter has a left-hand thread. The turning of the collar is counter-clockwise if you look toward it from the right side of the illustration. Bearing wear may be adjusted by turning up the left collar slightly more than the right.

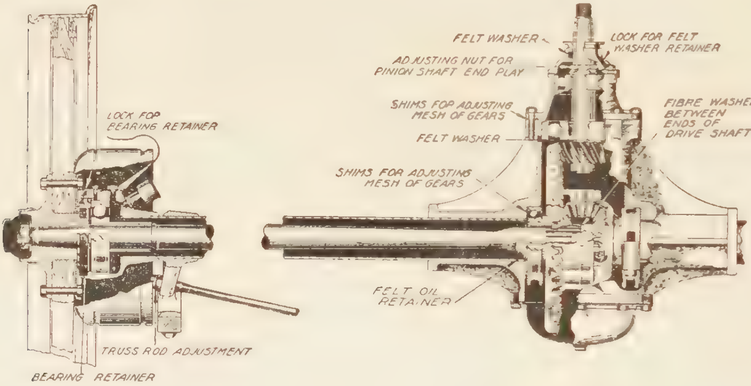

FELT WASHER
LOCK FOR FELT WASHER RETAINER
ADJUSTING NUT FOR PINION SHAFT END PLAY
SHIMS FOR ADJUSTING MESH OF GEARS
FIBRE WASHER BETWEEN ENDS OF DRIVE SHAFTS
LOCK FOR BEARING RETAINER
FELT WASHER
SHIMS FOR ADJUSTING MESH OF GEARS
FELT OIL RETAINER
TRUSS ROD ADJUSTMENT
BEARING RETAINER

Figure 115.—Semi-floating rear axle with ball bearings

BEVEL-PINION ADJUSTMENT

2007. The bevel pinion may be adjusted to mesh more closely with the ring gear by moving it toward the gear by adjusting a screw collar usually placed between the two bearings. Bearing wear may be compensated by an adjustment to be described presently.

2008. In passing, it should be noted that bevel pinion and ring gear may usually be adjusted without taking the axle apart. As a rule, it is only necessary to remove the rear cover plate. Absence of this plate generally indicates that the axle must be taken apart.

2009. The screw collars by which the ring gear is adjusted are locked in various ways. In Figure 110, two set screws on the front of the housing must be removed. In Figures 112, 113, and 114, the collar lock indicated must be removed. In many jobs it will also be necessary to slightly loosen the bearing clamps, one of which is shown in the right hand (Figure 116). In Figure 115 the bevel gear is adjusted by adding shims as shown. Complete disassembly of the axle is required to effect this adjustment.

2010. In most cars the pinion is brought into deeper mesh with the ring gear by drawing up on the front pinion bearing after slacking off on the rear-bearing adjustment, as shown in Figures 112 and 114, and then bearing wear is adjusted by drawing up on the front pinion bearing, and the same end is attained by removing shims from the pinion-bearing housing flange. In Figures 110 and 113, however, both pinion bearings are mounted in a sleeve, and the sleeve is turned to bring the pinion into deeper mesh with the gear. This difference, fortunately, does not affect the method of adjustment as already described.

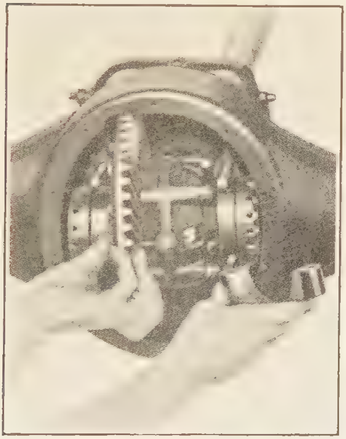


Figure 116

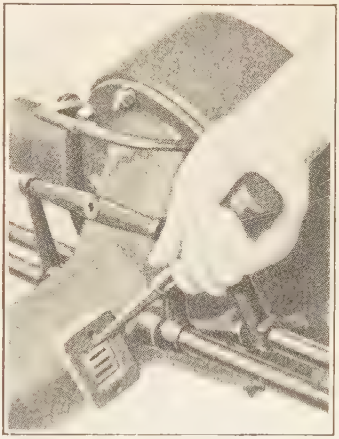


Figure 117

Figure 116.—Method of removing differential mechanism

Figure 117.—Method of adjusting bevel pinion when torque tube is used

ADJUSTMENT LOCKING DEVICES

2011. After examining the various illustrations the reader should have no difficulty in finding the pinion and pinion-bearing adjustments. In Figure 110 the propeller shaft bearing retainer lock must be removed and the clamp bolt must be loosened, after which the bevel pinion is adjusted by moving the sleeve with a screwdriver (Figure 117). On cars equipped with a torque tube the bevel-pinion bearing adjustment can not be made without removing the torque tube (see Figure 110).

2012. In Figure 112 the bevel pinion may be adjusted by removing a plate which exposes a sleeve similar to that shown in Figure 117. The bevel-pinion bearings are adjusted by drawing up on the pinion-bearing adjusting nut, after loosening the lock-nut.

2013. In Figure 113 the bevel pinion may be adjusted by turning the sleeve after the lock is removed. The pinion bearings are adjusted by drawing up on the pinion-bearing adjusting nut, after loosening the lock-nut.

2014. In Figure 114 the pinion is adjusted by turning the B-adjusting ring, after which the cap screws should be carefully tightened. The pinion bearings are adjusted by turning the M-adjusting ring, after loosening the E-clamp bolt.

2015. As a general rule, the pinion-bearings adjustment is the front one and the pinion adjustment the rear one.

BEVEL GEARS HUM

2016. Symptom—Gears hum.

2017. Causes—(1) Lack of lubricant. (2) Gear adjustment too loose. (3) Gear adjustment too tight. (4) Other troubles.

2018. Cure—1. Remove filler plug and fill with heavy gear oil up to level of filler opening. If there is any doubt as to proper level fill until bevel gear dips about 2 inches into the lubricant. For the average medium-size car, 2 pounds should be sufficient. If hum is very noticeable, run car as little as possible until axle is lubricated. If the axle is completely dry, a few miles running may be sufficient to ruin gears and bearings. If heavy oil is not available put in cylinder oil or grease temporarily.

2019. If axle housing leaks oil, tighten all nuts affecting axle joints, and if this does not remedy the trouble, consult your repairman.

2020. A gear adjustment too loose is ordinarily due to wear, but first see that all nuts on axle housing are tight. If the nuts are tight, the noise may generally be removed by adjusting the bevel pinion. Draw up the adjustment as tightly as possible without using force and then back off slightly. Jack up one rear wheel and run car in high gear.

If there is little noise, lock the adjustment; otherwise, vary the adjustment until minimum noise is noted. Some noise will be produced by the differential with one wheel off of the ground, and therefore when possible it is advisable to jack up both rear wheels. If the pinion-bearings adjustment is accessible, examine the pinion shaft for end play by pulling it back and forth with the hands. If the play is more than a slight amount, adjust the bearings, being careful not to remove all play. If in doubt as to the amount of play draw the bearing as tightly as possible without using force and then back nut off one-quarter turn. Be sure to lock the adjustment.

2021. Try the car on the road. If gears are quiet the adjustment is satisfactory. If they are noisy whether the engine is driving the car or the car is driving the engine, they are too loose, or gears or bearings are badly worn. If they are noisy only when the car is driving the engine, they are too tight, although here it must be explained that any axle in perfect adjustment will make a slight amount of noise, producing a trifle more noise when the car is driving the engine.

2022. If adjusting the bevel pinion fails to remove the noise, bevel pinion and ring gear should be adjusted together. Remove rear cover plate. The back edges of the teeth should be flush (see Figure 112), and either bevel pinion or gear should be adjusted until the teeth are flush. Then adjust pinion and gear simultaneously until just the slightest back lash is felt. With one rear wheel jacked up and cover plate removed try the car in high gear. If too noisy, vary pinion and gear adjustment until quietness is obtained, at the same time keeping the backs of the teeth flush.

2023. If ring gear is noticeably loose in its bearings, before adjusting it, draw up on bearing adjacent to back side of gear, until only a slight amount of bearing play remains.

2024. Draw up all nuts as tightly as possible, and replace all locking mechanisms, including any lock wires. As a rule, new lock wire is advisable.

2025. Cure 3. As a rule, if the adjustment is too tight humming will be noted only when the car is driving the engine. Adjust the gears as described in Cure 2.

2026. Cure—4. After a time the gears may become so badly worn that replacement will be necessary, and this point is hastened by lack of lubricant. Bearings may also wear to the point where replacement is necessary. If adjustment fails to cure the trouble, consult your repairman. Noise may also be due to loosening of the screws or rivets holding the bevel gear to the differential housing as well as to the loosening of almost any nuts or screws in the rear axle mechanism. Inspect all parts for tightness. If excessive noise is heard only when rounding a corner, the bearings in which the bevel gear rotates are loose or worn, or the differential gears are worn and require replacement. Adjustment of the bearings is feasible, as already described, if taper roller bearings are used. If cylindrical roller bearings are used, the thrust bearings adjacent to these bearings may be worn and require replacement. As a rule, ball thrust bearings are used, although sometimes a steel or bronze disc is employed.

REAR AXLE KNOCKS

2027. Symptom—Rear axle knocks.

2028. Cause—Probably broken tooth.

2029. Cure—A broken tooth either in the bevel pinion or gear will produce a knock or thump. Have a new part put in as soon as possible; meanwhile, drive car gently. The knock may also be due to some rotating part, such as a projection on a wheel, striking the axle housing.

CHAPTER XVIII

REAR WHEELS

2101. So far as passenger cars are concerned, rear axles may be divided into three types—semi-floating, three-quarter floating, and full-floating. These terms refer to the method of mounting and bracing the wheel to the axle housing.

SEMI-FLOATING AXLE

2102. Figures 110, 111, 114, and 115 show that in a semi-floating axle the wheel is bolted and keyed to the end of a tapered axle shaft, and that the *shaft* is supported by a bearing at the end of the axle housing as well as taking some support from the other end, which fits into the differential housing.

FULL-FLOATING AXLE

2103. Figures 118 and 119 show that in a full-floating axle the wheel is mounted on a double bearing which in turn is mounted on the *axle housing*. Therefore the axle shafts may be withdrawn without affecting the rolling of the wheels. In Figure 118 the axle shaft terminates in a flange which is bolted to the outside of the wheel, while in Figure 119 a jaw clutch on the end of the axle shaft meshes with a mating clutch member on the wheel hub. In the former case the axle may be withdrawn after the flange nuts are removed, and in the latter case, after the hub cap is removed.

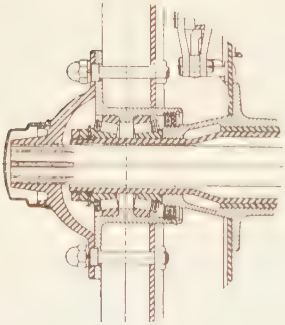


Figure 118. Full floating rear axle with driving flange bolted to wheel

THREE-QUARTER-FLOATING AXLE

2104. Figure 120 shows a three-quarter-floating axle. It will be seen that it is half-way between the other two types. It resembles the full-floating axle in that the wheel is mounted on a bearing mounted on the axle housing, but it also resembles the semi-floating axle in that the axle end is tapered. In Figure 120 the axle shafts are secured with nuts at their inner ends and the axle shafts can not be removed without taking the axle apart, but in most three-quarter-floating axles, the shafts may be withdrawn after the nuts holding the hub flange have been removed, just as in the case of the full-floating axle. In other words, as far as hub construction is concerned, the three-quarter-floating axle usually resembles the full-floating axle (Figure 118), except

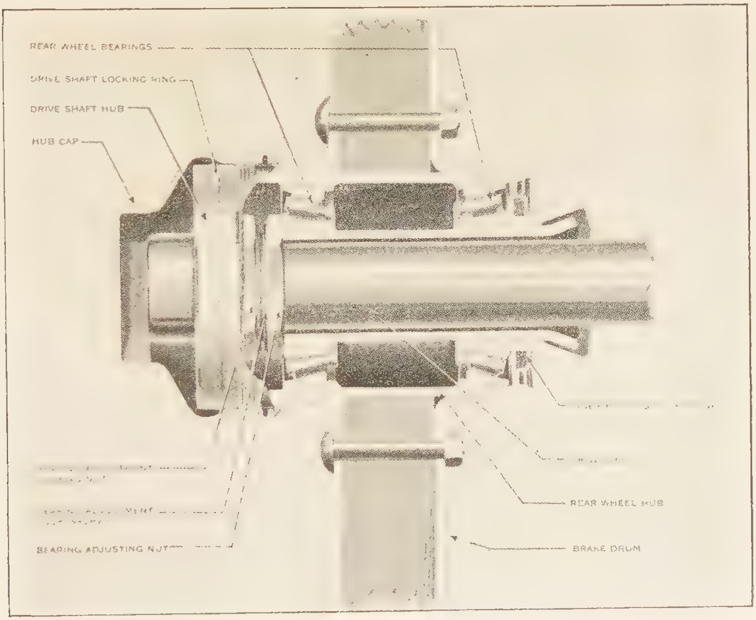

REAR WHEEL BEARINGS
DRIVE SHAFT LOCKING RING
DRIVE SHAFT HUB
HUB CAP
REAR WHEEL HUB
BEARING ADJUSTING NUT
BRAKE DRUM

Figure 119.—Full-floating rear axle with dog clutch wheel drive

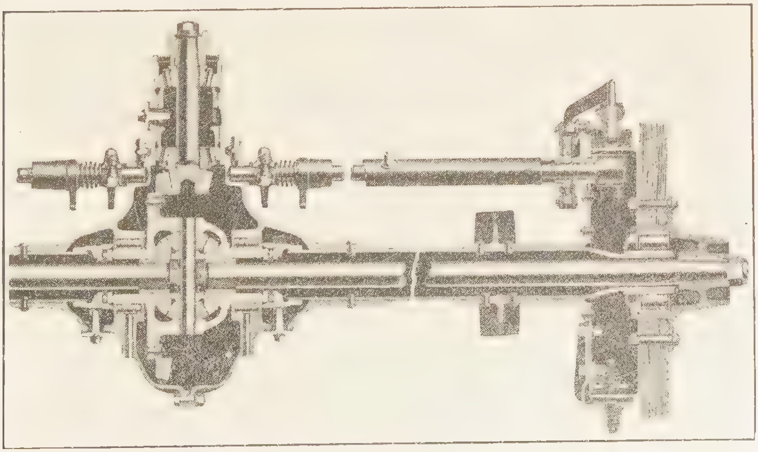


Figure 120.—Semi-floating rear axle equipped with roller bearings

that a single bearing instead of the double bearing shown is ordinarily employed. The axle shaft braces the wheel, and if the hub flange is loose on the axle shaft or the hub flange is loosely connected to the wheel, the wheel will wabble.

WHEEL REMOVAL AND BEARING ADJUSTMENT

2105. In all semi-floating axles (Figures 110, 114, and 115), the wheel is removed as follows: Take off the hub cap, remove the cotter-pin in the nut on the end of the axle shaft, remove the nut and then pull the wheel off. If the wheel is a very tight fit on the shaft, a wheel puller will be required, although in many cases the wheel may be loosened by striking the shaft end sharp blows with a lead hammer. A steel hammer will injure the axle end. The need of a wheel puller only emphasizes the fact that axle repairs should ordinarily be left to a man with the right equipment and experience.

2106. If the axle has taper roller bearings these may be adjusted after the wheels are removed. In Figure 110 the lock illustrated must be removed before the bearing adjusting collar can be turned up; and the same applies to Figure 114. Figure 115 has annular ball bearings which are non-adjustable. When these bearings are badly worn they must be replaced, or the old bearings may be reground and larger balls fitted by a specialist in this work.

2107. In most semi-floating axles, the axle shafts touch at their inner ends (Figures 110, 114, and 115). Consequently, tightening either wheel bearing tightens both bearings. Therefore, unless the bearings are exceedingly loose, it is sufficient to remove one wheel and adjust one bearing, but it is imperative that both wheels be off the ground. Adjust the bearing until it is tight but do not use force, then back off about one-eighth revolution, or until the bearing ceases to bind.

2108. If tightening one wheel bearing does not tighten the other, the inner axle ends are not in contact and each wheel bearing must be separately adjusted.

WHEEL REPLACEMENT

2109. In replacing the wheel be sure that key lies full in its slot and then draw the nut up tight, finally tapping the handle of the wrench sharply with a hammer to be sure that it is tight. Before replacing the wheel be careful to remove any grit from contacting surfaces which might prevent the hub tightly fitting the axle shaft. Inspect wheels after 200 miles to be sure that they are tight on their shafts. A wrench with a handle two or three feet long is desirable to tighten the taper nuts sufficiently.

2110. In the three-quarter-floating axle shown in Figure 120 the wheel bearings are cylindrical rollers, and therefore non-adjustable. The method of removing the wheel is the same as for semi floating axles. As already stated, in most three-quarter-floating axles the wheel is removed as follows: Remove nuts holding axle shaft flange to wheel, pull out axle shaft and flange as a unit. Remove lock-nut (or locking device) and bearing retaining nut on the end of the axle housing. Pull wheel off, using wheel puller if necessary. If taper roller bearings are used, the bearings may be adjusted as follows, but bear in mind that cylindrical roller bearings and ball bearings, except cup and cone, which are never used, are non-adjustable. With both wheels off the ground, and one axle shaft removed, release lock-nut on end of axle housing and then draw up on bearing retaining nut, until all play is removed from bearing, then slack off a fraction of a revolution until just a trifle play is felt. Then draw up lock-nut securely. In most cars there is a large soft steel washer between the two nuts and the edge of this is bent over to provide an additional lock. This washer must be bent straight, using a hammer and a drift, before loosening the lock-nut, and again after the adjustment is made, the washer must be bent back in place. After adjusting one wheel bearing, note whether play is removed from other wheel. If not, adjust other wheel bearing.

2111. To adjust wheel bearings on full-floating axles, remove hub caps and pull out both axle shafts (Figure 119), or remove axle flange nuts (Figure 118), and withdraw axle shafts. Jack up one rear wheel and adjust bearings, as described in paragraph 2106. Jack up the other rear wheel and adjust similarly.

WHEEL-BEARING LUBRICATION

2112. The wheel bearings should be packed with grease every 5,000 miles. It is also good practice, at this time, to remove the bearings and clean them in gasoline. The fact is, however, that few car owners care to go to this trouble or expense, and in most makes the wheel bearings will last for the life of the car, even if never cleaned.

2113. One method of lubrication is to force the grease into the bearing with a grease gun, but if this is not at hand, the bearing may be lubricated with good results by removing the flange or hub in three-quarter- and full-floating axles and filling it with grease, whereas semi floating axles require the removal of the wheels unless special provision is provided for lubrication as by the grease cup (Figure 115), or by the grease plug (Figure 114). Grease is introduced in the latter with a grease gun, and if grease is supplied regularly to the former no additional lubrication will be required

WHEEL HAS SIDE PLAY

2114. Symptom—Wheel has side play.

2115. Causes—(1) Bearings loose. (2) On semi- and three-quarter-floating axles the hub flange may be loose on the axle shaft, or loosely attached to wheel.

2116. Cure—1. Jack wheel up and shake it sideways. If play is ⅛ inch or more, adjust bearings if they are adjustable, as described in paragraph 2105. But first see Cure 2. If bearings are non-adjustable, replacement is required.

2117. Cure—2. On semi- and three-quarter-floating axles the hub flange may be loose on the axle shaft or loosely attached to the wheel. Remove axle shaft and examine. If any looseness is found, try to tighten nut on end of shaft. Whether nut can be tightened or not, the key is probably loose, both key and keyways in hub and shaft being worn. The keyway may be filed out by an experienced man and a larger key fitted, but it is generally cheaper and more satisfactory to put in a new axle shaft, new hub flange or both as required, together with a new key.

2118. In removing the nuts which hold the hub flange to the wheel note whether they are tight. If not, this looseness may be the cause of the play. Tighten all nuts and be sure that all are equipped with lock washers.

2119. It is possible to run a car a considerable distance with loose keys, although there is no telling just when they will break. Loose keys are particularly dangerous when the service brake is on the transmission, as a key breakage will render the brake ineffective.

BACK LASH

2120. Symptom—Back lash.

2121. Cause—Looseness in the driving mechanism anywhere between engine and rear wheels. It is indicated by a slight banging noise whenever the engine begins driving the car after the car has been driving the engine or the reverse. Jack up one rear wheel and place the car in high gear, and then rotate the wheel as far as possible first in one direction and then in the other. If the total movement is more than 2 inches, the play is excessive.

2122. Cure—If propeller shaft is exposed, note how far the wheel can be turned first in one direction and then in the other without moving the propeller shaft. If the movement is slight, the play is probably in the universals; if large, it is in the rear axle. Crawl under car and examine universal joints for play. If more than slightly perceptible looseness is observed, universals must be overhauled or replaced. See your repairman. If joints are very loose, drive the car as little as possible and as gently as possible until a repair is effected, as breakage is likely. However, if play is due to loose nuts, tighten them, and if the play disappears, the trouble may be forgotten. If the major portion of play is in the rear axle, examine the axle shafts for tightness in the hub flanges if the axle is semi- or full-floating, but if the latter, as shown in

Figure 119, see that teeth of the dog clutch on the end of axle shaft are not worn. If so, consult your repairman.

2123. If there is no play between axle shafts and wheels, there is probably excessive back lash between bevel pinion and ring gear, and adjustment is required as described in paragraph 2001. If this fails to remove the back lash, consult your repairman, as there are many other places it may occur. The ring gear may be loose on the differential housing, or the axle shafts may be worn where they fit into the differential driving gears, the differential gears may be worn, and so forth.

CLICK OR KNOCK

2124. Symptom—Slight click or knock.

2125. Cause—Looseness between axle shaft and wheel, noted commonly when engine is accelerated or retarded.

2126. Cure—On semi- and three-quarter-floating axles see that hub flange is not loose on axle shaft. If so, tighten nut if possible, but in any case the key may be loose and your repairman should be consulted. If full-floating axle, look for looseness between teeth of dog clutch on end of axle shaft. In either case, new parts will probably be required.

KNOCKS FROM BREAKAGE

2127. Symptom—Knock.

2128. Cause and Cure—For knocks produced by broken bevel pinion or ring gear teeth, see paragraph 2027. For other knocks, consult your repairman.

HUM OR KNOCK

2129. Symptom—Hum or knock.

2130. Cause—Breakage or balls or rollers in bearing.

2131. Cure—Examine bearing and if balls or rollers are broken or chipped, replace at the earliest possible moment. Sometimes, when the bearing gives way completely the wheel may come off and perhaps cause a serious accident, especially if it slips out just far enough to render the brakes ineffective.

SCRAPING

2132. Symptom—Scraping sound.

2133. Causes—(1) Brake dragging. (2) Lack of lubricant. (3) Bearing breaking. (4) Bearing worn.

2134. Cure—1. Examine brakes; for further details see paragraph 2209. Note that the brake may drag due to too tight an adjustment, or to brake drum or shoe being out of round, or to the drum being loose, or to the axle shaft being bent if the axle is semi- or three-quarter-floating.

2135. Cure—2. See that wheel bearings are properly lubricated.

2136. Cure—3. If signs of bearing breakage are noted, or small metal chips are found in bearing grease, have the bearing replaced.

2136A. Cure—4. If the bearing is badly worn, it should be adjusted or replaced.

SQUSHING SOUND

2137. Symptom—Squshing sound.

2138. Cause—One or more demountable rim nuts may be loose.

2139. Cure—Tighten all nuts. If threads are badly worn have new screws put in; this can be done in a moment. If rim wedges bear against a locking ring, see that ends of ring come together at the middle of a wedge.

WHEEL WABBLE

2140. Symptom—Wheel wabbles.

2141. Causes—(1) Axle shaft bent. (2) Wheel bent out of true.

2142. Cure—1. If an axle is semi- or three-quarter-floating, the wabble may be due to a bent axle shaft. Jack wheel up and place a mark at the center of the hub cap, and rotate the wheel. If this mark describes a circle, the axle shaft is bent. Have your repairman straighten or replace axle shaft as required. In some cars the shaft may be straightened without removing it. Cure—2. If the mark on the hub cap rotates as the center of the wheel, the axle is true but the wheel is bent. Consult your repairman. If the wheel is a disc type, see that nuts holding it to hub flange are tight.

WHEELS SQUEAK

2143. Symptom—Wheels squeak.

2144. Cause and Cure—On wooden wheels, tighten nuts holding hub flanges to spokes. Exceptionally hot, dry weather may cause spokes to shrink and squeak. Try wetting the spokes occasionally, or use an anti-squeak compound made especially for wooden wheels. If these remedies prove ineffective, new wheels will be required or the old wheels may be rebuilt. If wire wheels squeak, have the spokes tightened by a competent man. A squeak may also be due to too tight a bearing, need for lubrication or loose demountable rim nuts.

LUBRICANT LEAKS

2145. Symptom—Lubricant leaks out.

2146. Cause and Cure—If lubricant leaks out of the hub flange tighten hub flange nuts, and if this is not sufficient, put in a new gasket made of wrapping paper, first completely removing the old. If lubricant leaks on to brakes, withdraw some lubricant from the axle housing if it has recently been filled; otherwise, new oil washers will be required. If proper installation of oil washers on a semi-floating axle is difficult, try forcing a half-dozen washers about a foot in on each axle shaft.

CHAPTER XIX

BRAKES

2201. All cars built today are equipped with pedal-operated brakes acting on all four wheels while the hand brake, intended almost entirely for parking, acts at various points on various cars. It may act on a drum on the drive shaft just to the rear of the transmission, or on the rear wheels either through separate bands or shoes or by applying the rear brakes of the 4-wheel braking system. On a few makes, the hand lever applies all four brakes just as the pedal does.

2202. Braking action is secured either by expanding internal shoes against a drum or by contracting an external band against a drum, the former being known as an internal brake and the latter as an external brake.

2203. The shoe or the band is faced with brake lining because metal-to-metal surfaces would wear too rapidly. The lining is riveted to the band or shoe, and is usually made of asbestos yarn containing a copper or brass wire to give it strength. The yarn is woven into a tape of suitable width and thickness, and is then impregnated with some compound under heat and pressure to give a rather hard, wear-proof, moisture-proof, homogeneous material.

2204. Figure 121 shows a rear-brake mechanism which is typical for

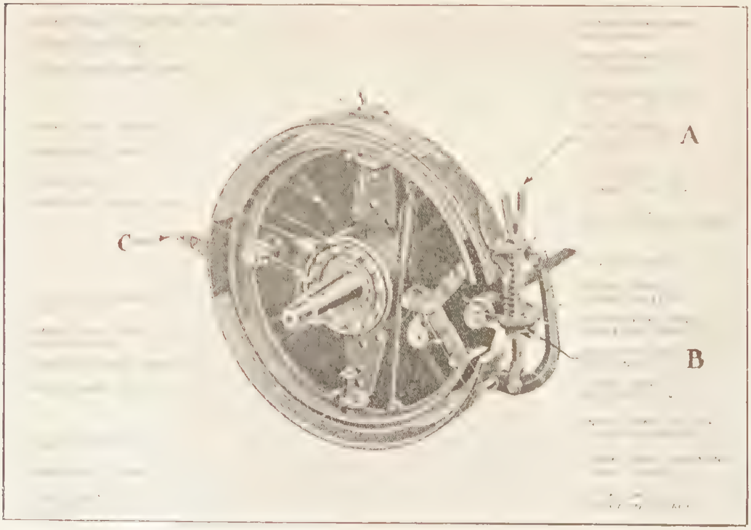


Figure 121.—Typical rear-wheel brake mechanism

earlier cars. The wheel with the brake drum attached has been removed to show the construction clearly. When the pedal is depressed the external band is contracted, gripping the drum, and when the hand lever is pulled up, the internal shoe expands against the drum. The brake pedal is connected to the contracting band by a suitable system of rods and levers, and the hand lever is similarly connected to the expanding shoes (Figure 122). The brake linkage usually contains an equalizer bar (similar to a whiffletree), although sometimes a gear equalizer similar to a differential mechanism is used, and sometimes no equalizing mechanism is employed. The purpose of the equalizing mechanism is to apply the brakes equally on both wheels. If one brake grips the wheel harder than the other, the latter is shirking its duty and stopping ability is reduced.

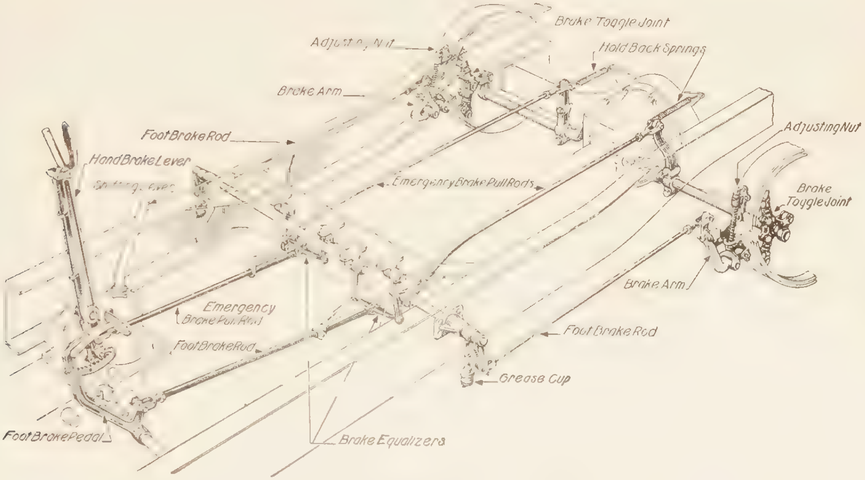

Brake Toggle Joint
Adjusting Nut
Hold Back Springs
Brake Arm
Adjusting Nut
Foot Brake Rod
Hand Brake Lever
Shifting Lever
Emergency Brake Pull Rods
Brake Toggle Joint
Brake Arm
Emergency Brake Pull Rod
Foot Brake Rod
Foot Brake Rod
Grease Cup
Foot Brake Pedal
Brake Equalizers

Figure 122.—How pedal and hand lever are connected with rear brakes

2205. Internal shoes are sometimes expanded by a cam instead of by the toggle mechanism shown in Figure 121. Sometimes the external brake is discarded and two sets of internal brakes are used, one connected to the pedal and the other to the hand lever, the brake shoes either being placed side by side on a double width drum, or concentric, acting on two drums, one larger than the other.

2206. On some cars only one brake acts on the rear wheels, the other brake being mounted on the drive shaft just to the rear of the transmission (Figure 123). Either brake, of course, may be an internal or external type.

Figure 123.—Transmission brake

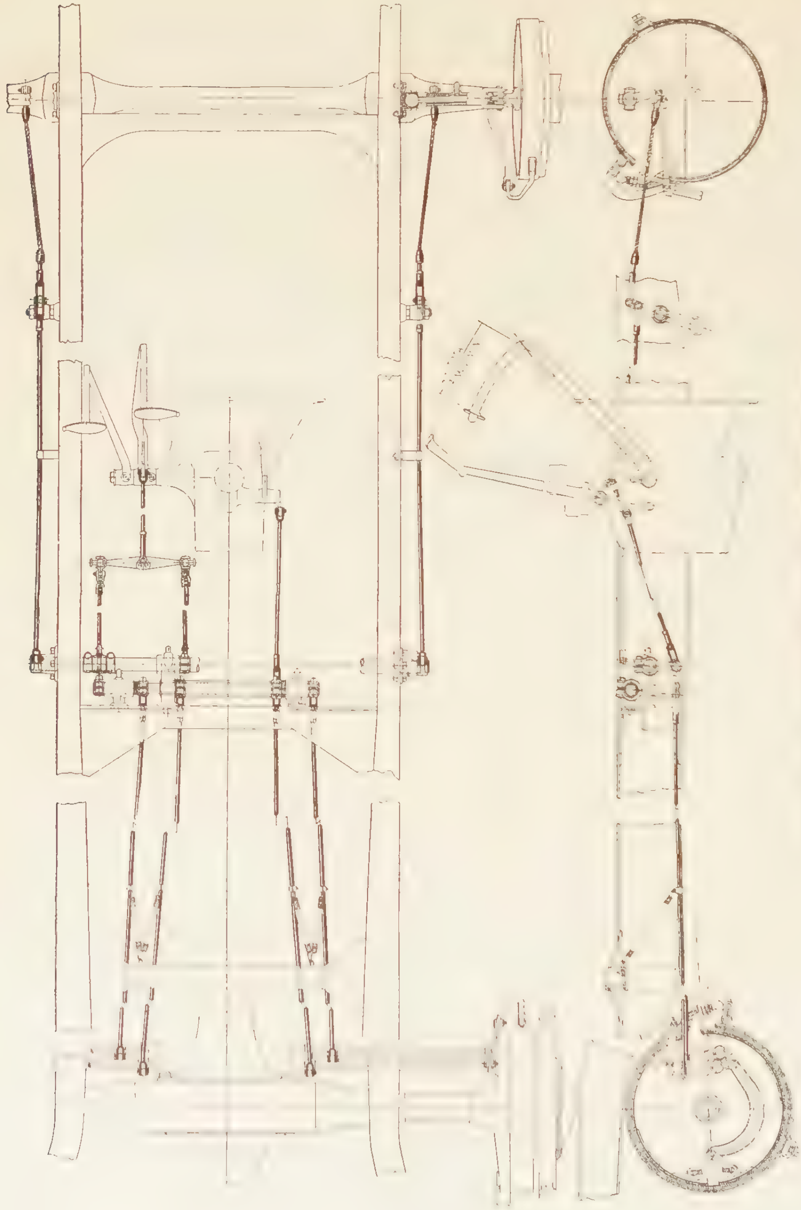


Figure 124.—Typical 4-wheel brake mechanism

FOUR-WHEEL BRAKES

2207. A typical 4-wheel brake mechanism is illustrated in Figure 124. The front-wheel linkage, of course, must be so designed that turning the front wheels does not interfere with the braking action, but except for this difference the linkage controlling the front wheels duplicates the linkage acting on the rear-wheel brakes.

2208. A number of cars use the Lockheed hydraulic 4-wheel braking system (Figure 125), in which the brakes are applied by liquid pressure produced by depressing the brake pedal. The brake pedal is connected to a piston operating in a cylinder from which run pipes to individual pistons and cylinders mounted on each brake band or shoe, the whole system being full of liquid. When the brake pedal is pushed down pressure is generated in the main cylinder and instantly transmitted to the individual cylinders, thus applying the brakes. The advantages of the system include: Perfect equalization of brakes; elimination of friction in the brake mechanism — thus all power supplied to the brake pedal is used to apply the brakes; wear and rattle of brake linkage is avoided; and there are no parts to be lubricated.

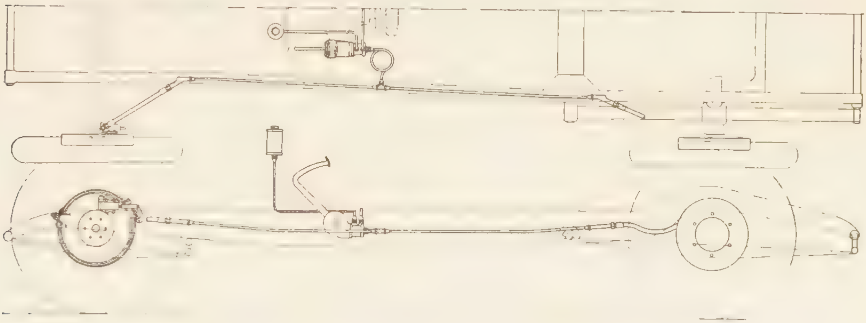


Figure 125.—Lockheed hydraulic 4-wheel brake system

BRAKE ADJUSTMENT

2209. On all cars equipped with a braking mechanism similar to that shown in Figure 121, the contracting bands always have an adjusting nut *A*, and usually also have adjustments at *B* and *C*.

2210. The man who is not mechanically inclined, who finds it necessary to adjust his brakes on the road, should give the nut *A* on each rear wheel a half-turn clockwise, and if this does not improve the braking action sufficiently, give each nut an additional half-turn, and so on, but the nuts should never be turned enough to bring the bands closer than $\frac{1}{32}$ inch to the drums. After making this adjustment the drums should be checked for heating as described in paragraph 2212. On cars equipped with 4-wheel brakes the specified clearance is likely to be $\frac{1}{64}$ inch.

2211. If *A* is the only adjustment, screw down on this nut until the band is approximately $\frac{1}{32}$ inch from the drum all around. Adjust the bands on both wheels the same amount and then test the brakes for equalization by locking the wheels when proceeding at 5 miles an hour on a dusty, sandy, or muddy road, or wet pavement. If one wheel locks before the other as noted by the wheel marks on the road, reduce the adjustment on this wheel or increase it on the other until best equalization is obtained. Equalization is required in spite of the fact that brake equalizers are fitted.

CAUSE OF HEATING

2212. After brakes have been adjusted, run the car a few miles and then feel the drums. If warm or hot, the brakes are adjusted too tightly. Do not make this test immediately after using brakes.

2213. If there are also adjustments at *B* and *C*, it is not necessary to use them as long as turning down on *A* brings the band approximately $\frac{1}{32}$ inch away from the drum all around. (Figure 121.)

2214. If nut *A* does not provide a proper adjustment, examine the band at *C*. If the band does not stand $\frac{1}{32}$ inch from the drum, adjust *C* until it does. Then adjust *B* until the lower half of the band stands $\frac{1}{32}$ inch from the drum. To do this, loosen the lock-nut and then screw *down* on the adjusting nut to bring the band closer to the drum, and then tighten the lock-nut securely. Adjust the nut *A* until the upper half of the band is $\frac{1}{32}$ inch from the drum.

2215. If additional adjustment is required, the pull rod attached to the brake pedal may be shortened.

ADJUSTING SPECIAL BRAKES

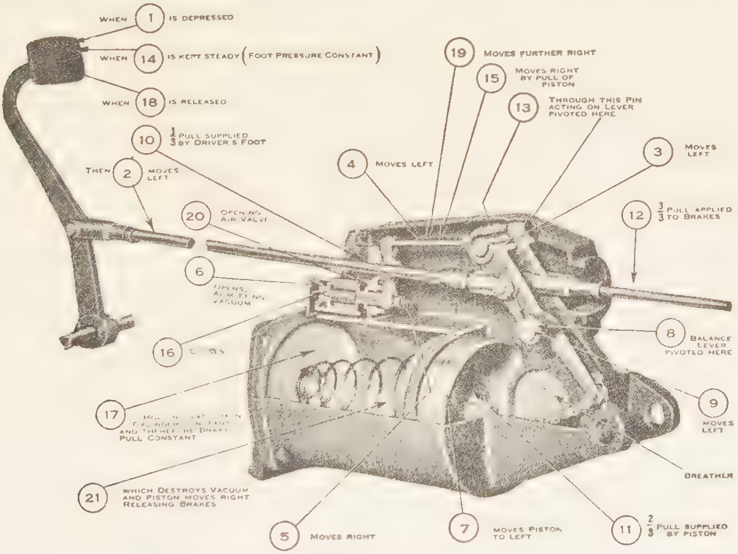
2216. Expanding brakes of the type shown in Figure 121 are usually adjusted by shortening the pull rod attached to the emergency brake lever, but do not shorten it sufficiently to cause the brakes to drag. In making this adjustment jack up one rear wheel and be sure that brake is not drawn tight enough to drag. Then jack up the other rear wheel and note if it drags. Check adjustment on road as described in paragraph 2212.

2217. Transmission brakes are usually taken up by some simple and obvious adjustment, as illustrated in Figure 123. Adjust until the brake band is $\frac{1}{32}$ inch from the drum. If the adjustment is not obvious, it is advisable to have it made by an experienced man.

2218. In many cars the adjustment of internal brakes is not obvious, and inasmuch as it is impossible to describe all the different adjustments now in use, let alone new brakes that are being brought out, it is advisable when the adjustment is not clear to leave the job to an experienced man, and cars with 4-wheel brakes had best be adjusted by a dealer selling this make of car—unless the adjustment is obvious and readily made.

POWER-OPERATED BRAKES

2219. Power-operated brakes are being used to a limited extent. The large 1928-29 Pierce-Arrow, the 1929-30 Stutz and Blackhawk, and the 1928 Chandlers, except the smaller Six, for example, use a vacuum piston to assist in the operation of the brake pedal. In other words, when the driver puts his foot on the pedal, instead of supplying the full force he supplies approximately one-third of the force, the other two-thirds being supplied automatically by the vacuum piston which is connected to the intake manifold. Figure 126 explains the mechanism used on the Chandler, its principle may be readily understood by reading the explanatory items consecutively, beginning with number one.



WHEN ① IS DEPRESSED
WHEN ⑭ IS KEPT STEADY (FOOT PRESSURE CONSTANT)
WHEN ⑱ IS RELEASED
⑩ 1/3 PULL SUPPLIED BY DRIVER'S FOOT
THEN ② MOVES LEFT
⑳ OPENING AIR VALVE
⑥ OPENS, ADMITTING VACUUM
⑯ CLOSES
⑰ HOLDS VACUUM IN CYLINDER CONSTANT AND THEREFORE BRAKE PULL CONSTANT
(21) WHICH DESTROYS VACUUM AND PISTON MOVES RIGHT RELEASING BRAKES
⑤ MOVES RIGHT
④ MOVES LEFT
⑲ MOVES FURTHER RIGHT
⑮ MOVES RIGHT BY PULL OF PISTON
⑬ THROUGH THIS PIN ACTING ON LEVER PIVOTED HERE
③ MOVES LEFT
⑫ 3/3 PULL APPLIED TO BRAKES
⑧ BALANCE LEVER PIVOTED HERE
⑨ MOVES LEFT
BREATHER
⑦ MOVES PISTON TO LEFT
⑪ 2/3 PULL SUPPLIED BY PISTON

Figure 126.—Westinghouse vacuum brake

2220. Fundamentally, the device consists of a cylinder and piston of ample size, the piston being connected to the brake linkage so that when the brake pedal is depressed, a suction valve to the intake manifold is opened permitting engine suction to act on the piston and thus supply two thirds of the braking power, one-third being supplied by the driver's foot. When the brake pedal is released, the suction valve is closed and an atmospheric valve is opened, thus killing the vacuum in the cylinder and permitting the brakes to release. A feature of the system is that the pedal pressure increases as the pedal is depressed, just as it does in conventional braking systems. This really is an important point, as otherwise the driver would be likely to apply the brakes too hard and lock the wheels. If through some unusual circumstance the device becomes inoperative the brakes may be applied as usual, the foot supplying the full effort.

FOUR-WHEEL BRAKE ADJUSTMENT

2221. The proper adjustment of 4-wheel brakes frequently requires the services of an expert. Furthermore, the systems on the different cars vary so greatly in detail that it is impossible on the one hand to give general instructions which will apply to them all; on the other hand, there is not space in this book to discuss the adjustments of each system in detail, and even if there was, instructions given concerning a particular make today might not apply completely two months hence. Consequently, the most feasible plan appears to be to select a few of the more popular systems for discussion.

LOCKHEED EXTERNAL BRAKES

2222. The following directions, supplied by the Chrysler company, apply in a general way to all cars equipped with the Lockheed external system:

Connected to the brake foot pedal is a piston working in a master cylinder (Figure 127), which is bolted to the left-hand side of the transmission case. Leading from this master cylinder to cylinders in each of the four

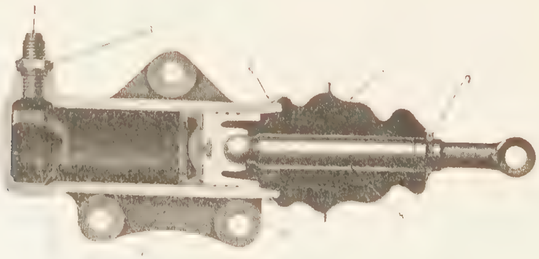


Figure 127.—Master cylinder for brake:

1—Supply tank tube union
2—Piston stop
3—Supply tank tube union gasket
4—Piston cup expander
5—Boot wire (long)
6—Piston cup
7—Boot
8—Piston and rod assembly
9—Boot wire (short)

brake drums are copper tubes and armored hose connections. In each brake drum cylinder (Figure 128), are two pistons, each of which is connected through a lever to an end of the brake band. The whole system—that is, all cylinders and lines—is full of liquid, all the air having been expelled in the process of filling. There is no pressure in the system when the brakes are not in operation, and the brake-band linings are held clear of the drums by the brake return springs.

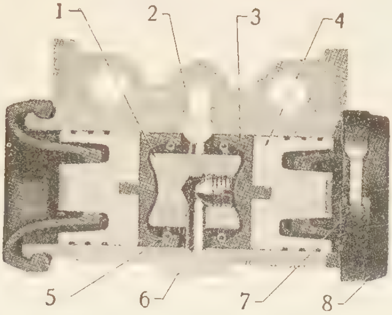


Figure 128.—Wheel cylinder:

1—Piston cup stop
2—Piston cup stop pin screw
3—Piston cup
4—Piston and plug assembly
5—Piston cup expander
6—Piston cup stop pin
7—Boot strap
8—Boot

2223. When the pedal is depressed, the piston in the master cylinder moves back, expelling into the lines sufficient liquid to force out the pistons in each of the brake-drum cylinders until the brake bands come in contact with the drums.

2224. There can be no braking pressure applied to any one drum until all bands are in contact with their drums. The greater force required to give braking pressure can not be supplied until the resistance in all wheel cylinders is built up to that force. This is governed by the physical law that force or pressure exerted upon a body of liquid is transmitted equally in all directions. With the four brake bands at the point of braking, the additional pressure of the pedal is naturally transmitted equally to all brakes, giving a positive braking action, absolutely self-equalizing in its application.

2225. When the brake pedal is released, the pistons in the brake-drum cylinders are returned to their stops by the brake return springs; this forces the liquid, used in displacing the pistons, through the lines back into the master cylinder.

2226. The level of the liquid in the supply tank on the dash should not be below the one-half full position. The supply of liquid should be checked once a month and replenished if necessary. Unless there are leaks in the system it will require replenishing only about once every 6 months. Lockheed hydraulic brake liquid should be used to the exclusion of all other liquids in the braking system or corrosion may result. The total capacity of the system is 1½ pints. The pump handle on the supply tank should be in the locked position; this is accomplished by pushing the handle down to the limit of its travel and turning to the right until positively seated.

2227. The anchors on the brake bands should be oiled each 2,000 miles and their action checked to see that they work freely. There are no other points in the hydraulic brake operating mechanism requiring lubrication.

2228. The pedal is set for clearance between the pedal and the floor board, on each individual car, at the factory. Readjustment in the field will not be necessary and improper adjustment will result in decreasing the effective travel of the master cylinder piston.

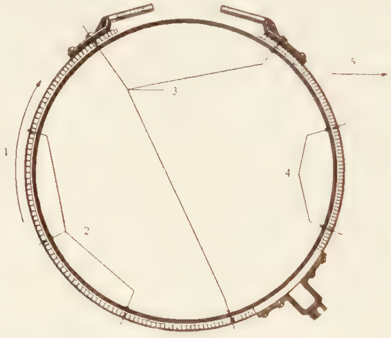


Figure 129.—Wheel brake-band adjustment:

1—Direction of drum rotation
2—0.015-inch clearance
3—0.010-inch clearance
4—0.015-inch clearance
5—Direction of car travel

2229. The brake bands (Figure 129), should conform to the brake drum—that is, they should form a circle. With the pedal in the release position, the bands should be adjusted with 0.010- to 0.015-inch clearance between brake band and drum at all points. This adjustment is made through the hexagonal nuts on the threaded ends of the brake bands and a screw at the anchor plate. The clearance can best be established by use of a 0.010-inch feeler, which should slip between band and drum at any point without binding. To avoid excessive take-up at the brake-band ends, clearance should not be greater than 0.015 inch. The brake-band brackets at the anchor pins should move in and out freely.

2230. Loss of liquid, air in the lines due to broken connections, or a leaking or unlocked supply tank valve are the only causes for any change in the effective movement of the brake pedal, which can easily be detected by a free movement of the brake pedal before resistance in the master cylinder is felt.

2231. When this looseness becomes appreciable—that is, ¾ inch of the pedal movement it should be corrected as follows: With the brake bands releasing fully and foot pressure released from the pedal, the pump handle on the supply tank should be released by turning to the left until it is free to move up and down. The pump handle should then be given a few strokes up and down until the foot pedal no longer has the free movement. After this has been done, a pause of several seconds should be made to permit excess liquid in the lines to back up into the supply tank, then the valve is closed at the bottom of the pump by depressing the pump handle and turning to the right until firmly seated. It is important that the pump handle be locked tight so that no liquid can be returned to the tank under pedal pressure.

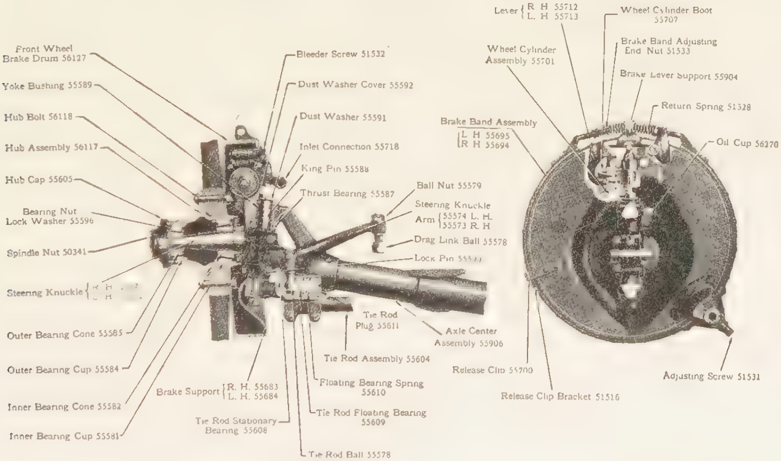

Front Wheel Brake Drum 56127
Yoke Bushing 55589
Hub Bolt 56118
Hub Assembly 56117
Hub Cap 55605
Bearing Nut Lock Washer 55596
Spindle Nut 50341
Steering Knuckle R H / L H
Outer Bearing Cone 55585
Outer Bearing Cup 55584
Inner Bearing Cone 55582
Inner Bearing Cup 55581
Bleeder Screw 51532
Dust Washer Cover 55592
Dust Washer 55591
Inlet Connection 55718
King Pin 55588
Thrust Bearing 55587
Ball Nut 55579
Steering Knuckle Arm 55574 L. H. / 55573 R. H
Drag Link Ball 55578
Lock Pin 555
Tie Rod Plug 55611
Axle Center Assembly 55906
Tie Rod Assembly 55604
Floating Bearing Spring 55610
Tie Rod Floating Bearing 55609
Tie Rod Ball 55578
Brake Support R. H. 55683 / L. H. 55684
Tie Rod Stationary Bearing 55608
Lever R H 55712 / L. H 55713
Wheel Cylinder Boot 55707
Wheel Cylinder Assembly 55701
Brake Band Adjusting End Nut 51533
Brake Lever Support 55904
Return Spring 51528
Brake Band Assembly L H 55695 / R H 55694
Oil Cup 56270
Release Clip 55700
Release Clip Bracket 51516
Adjusting Screw 51531

Figure 130.—Lockheed front external brake

2232. If the foregoing does not eliminate excessive pedal travel, the condition can only be due to air in the lines and it will be necessary to "bleed" the lines as indicated in paragraph 2234.

2233. The brake-pedal stop-screw adjustment and the brake piston rod lock-nuts are properly adjusted when the car is built and should not be disturbed; as improper adjustment will result in decreasing the effective travel of the piston in the master cylinder.

2234. The cap screw, No. 51,532 (Figure 130), should be removed and the bleeder nipple and hose attached (part of car tool equipment) to the bleeder valve in the wheel cylinder with a small open end wrench. The bleeder valve should be opened from ½ to ¾ turn, but not completely removed. One end of the rubber tubing should be slipped over the exposed end of the bleeder valve and the other end of the tubing laid into a clean and dry container, preferably a pint bottle. The latter should be resting on the floor.

2235. With foot pressure removed from the brake pedal, the valve in the supply tank should be opened by turning the handle to the left until it is free to move up and down. By means of this handle, liquid should then be pumped into the system, which will force the liquid out of the brake-drum cylinder into the container. When the lines are being filled by pumping, the cap at the top of the tank should be released at least one turn to ensure proper venting. The cap should then be tightened with fingers only and *not with a tool.* After about ½ pint of liquid has been drained from the system and it is observed that air bubbles still remain in the liquid, coming out of the rubber tubing, the bleeder valve should be closed and the cap removed from the supply tank. The liquid drawn from the system should then be poured back into the supply tank. The operation should be repeated until no more bubbles appear. It may be necessary to apply this operation to all four brake-drum cylinders to ensure air being removed from all lines.

2236. It will be necessary to bleed the lines to remove air from the system after disconnecting one of the brake-drum cylinders for removal of axle parts, or if a connection or pipe should break.

2237. An excessive consumption of liquid denotes a leak in the system. This can easily be detected by applying heavy pressure to the brake pedal while the car is standing still and then checking over the various connections to see the point of breakage.

2238. In exceptionally hot weather, a slight brake drag may be noticed. This is due to either too much liquid having been pumped into the system or to expansion of the liquid under heat. The correction is to open the supply tank valve for a few seconds. Care must be taken not to press on the foot pedal while this valve is open. After the valve has stood open for a few seconds, it should again be closed.

2239. Caution. Pistons or any other parts of the master cylinder or brake drum cylinders should never be removed. Special tools are required to assemble these parts correctly. There is nothing in these cylinders to give trouble but, if it should be necessary to make a service repair, a complete cylinder assembly should be used.

LOCKHEED INTERNAL BRAKES

2240. The following directions, supplied by the Franklin company, apply generally to cars equipped with the Lockheed internal system:

The Lockheed hydraulic internal 4-wheel brake is simple in construction and operation. It consists of a cylinder in each wheel and a master cylinder

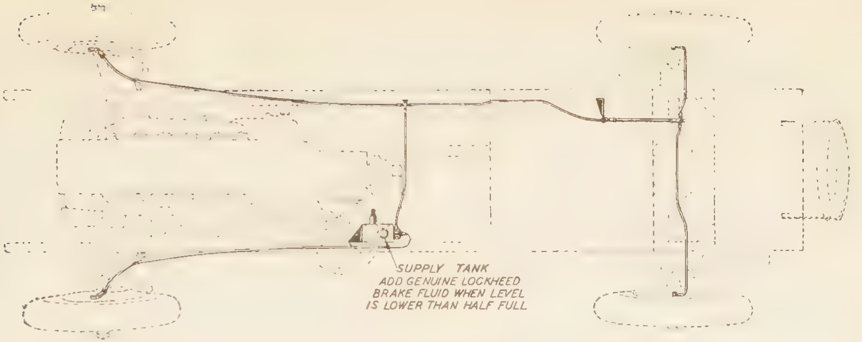


Figure 131.—Lockheed hydraulic internal braking system

connected to the foot lever (Figure 131). The wheel cylinders contain opposed pistons to which the brake shoes are attached. The master cylinder contains a single piston.

2241. When the brake pedal is depressed, the master cylinder forces a fluid through copper tubing and armored rubber hose to each of the wheel cylinders (Figure 132). The fluid enters the wheel cylinders between the two opposed pistons, forcing them apart and thus applying the two brake shoes. When the brake pedal is released, springs between the brake shoes bring the pistons in the wheel cylinder, back to the normal position, forcing the fluid back through the master cylinder.

2242. The master cylinder is immersed in a small tank (Figure 133), which contains a reserve supply of the liquid. This tank should be kept at

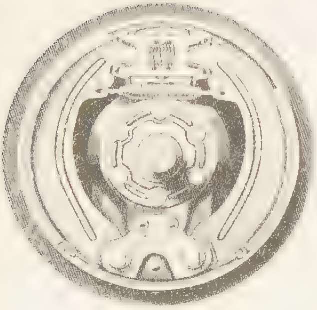


Figure 132

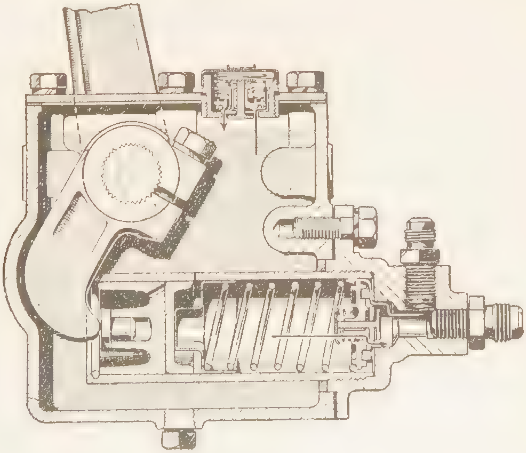


Figure 133

Figure 132.—Lockheed internal brake

Figure 133.—Lockheed master cylinder combined with supply tank

least half full of Lockheed hydraulic brake fluid; none but this fluid should be used. The genuine fluid can be obtained from the Wagner Electric Corporation, St. Louis, Missouri, or from one of the many branches of this firm throughout the country, or from automobile dealers handling cars equipped with this system.

2243. Inspect the supply tank once a month. One filling should last about a year. If frequent additions of fluid are necessary, examine the system for fluid leaks.

2244. As shown in Figure 133 all Lockheed internal-brake systems have what is known as a self-compensating master cylinder; that is, the liquid from the supply tank is delivered automatically as required to the braking system, and the correct amount of liquid is maintained in the braking system whether atmospheric temperatures are high or low or whether the car is hot or cold, thus braking action remains unchanged regardless of temperature variations. No hand pumping is required with this system. As illustrated in Figure 133, the supply tank is integral with the master cylinder, although in some installations the supply tank is placed on the dash as formerly, a pipe running from here to the supply port in the master cylinder.

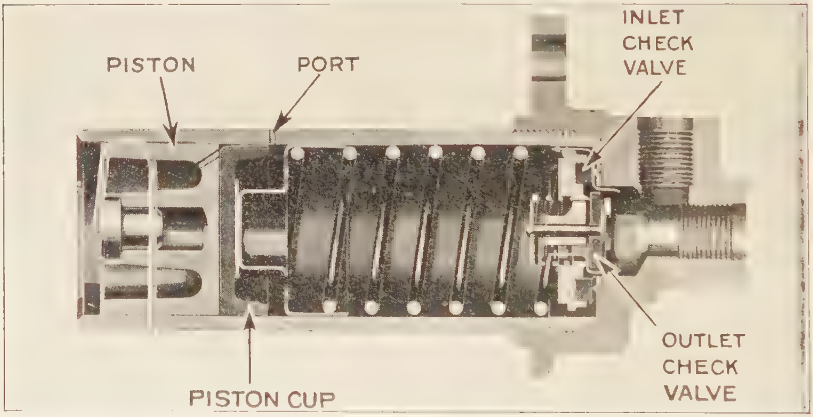


Figure 134.—Details of master cylinder in Franklin car

2245. Looking at the master cylinder (Figure 134), it will be seen that there is a port between the master cylinder and the supply tank which permits liquid to flow from one chamber to the other as required. This port is closed by the rubber cup on the master piston as soon as the pedal is moved.

2246. At the other end of the master cylinder there are two spring closed valves. The inner valve opens under ½ pound pressure when the pedal is depressed, allowing pressure to flow through the braking system. When the pedal is released, liquid flows back from the system to the master cylinder until pressure in the system drops to 6½ pounds when the outer valve closes.

2247. If leakage occurs in the system, it is automatically refilled and brought back to 6½ pounds pressure at the first succeeding piston-stroke and the master cylinder is filled when pedal is released, although if during the return stroke the vacuum in master cylinder rises higher than 1½ pounds, the cup collapses and liquid flows in through the passages at the back of the cup.

2248. If reduction in temperature causes contraction of the liquid in the braking system, automatic opening of the central valve makes up the loss. If increased temperature raises the pressure in the system, the excess is discharged through the outer valve.

2249. The two valves in the top of the supply tank are similar in design to those at the right end of the master cylinder. The central valve opens inward under ¼ pound pressure while the outer valve opens outward under ½ pound pressure. This arrangement permits air to flow into the supply tank to allow liquid to flow by gravity into the master cylinder, yet it prevents discharge of air with slight rise in pressure in the supply tank. Under normal operation, air may come in but it can not get out, therefore evaporation of fluid is negligible.

PEDAL OPERATION

2250. The cause of poor brakes is indicated by the manner in which the pedal operates. Brake pedal operation can be in three ways, as follows: (a) Pedal goes to floor with comparatively little effort; brakes don't hold. This condition is probably due to normal wear of brake lining. Also, although the condition is rare, it can be due to a fluid leak. If it is due to a leak, the level of fluid in the supply tank will be found low. (b) Pedal can be pushed to floor with effort, but brakes don't hold. This condition is an indication of air in the pipe lines. (c) Brake pedal can not be pushed to floor but brakes don't hold.

2251. This condition is an indication of water or grease on the brake linings. As the brake shoes are exceptionally well protected from both water and grease, this trouble is rarely encountered.

2252. Should the front wheels tend to pivot or to turn to one side when the brakes are applied, the trouble is due to unequal braking on the front wheels. As all brake shoes are always applied to the drums with equal pressure, any unequal braking effect is due to a brake lining defect. The defect may be due to high spots on the lining, to water or grease on the lining, to a slight looseness between the brake assembly and the steering knuckle, or to a faulty adjustment of the shoe pivots or to the use of some unsuitable lining. It is important that the lining in both front wheels be maintained in uniform condition.

2253. Grabbing is commonly caused by the toe (upper end) of the shoe making contact before the heel (lower end). The remedy is to dress down slightly the lining on the toe. The pivots at the bottom of the brake shoes are adjusted to give 0.005 inch clearance at the heel and 0.010 inch at the toe. This adjustment is factory set and should never be changed except when installing a new dust shield, a new wheel, a new brake drum, or a new steering knuckle.

PEDAL CLEARANCE

2254. It is essential that the brake pedal have ½-inch free movement at the foot pad before the brake lever engages with the piston in the master cylinder. This clearance is necessary to ensure that the master cylinder releases enough to uncover the small port shown in Figure 134. If this port is not uncovered, or if it should become clogged with dirt, the fluid would have no chance to escape from the pipe lines when it becomes expanded by heat. Consequently, pressure would be built up in the system and the brakes automatically applied.

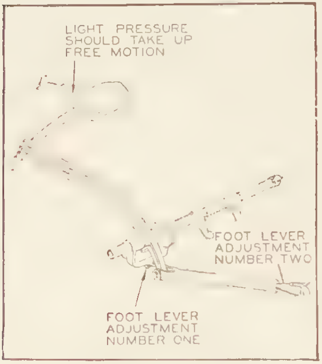

LIGHT PRESSURE SHOULD TAKE UP FREE MOTION
FOOT LEVER ADJUSTMENT NUMBER TWO
FOOT LEVER ADJUSTMENT NUMBER ONE

Figure 135

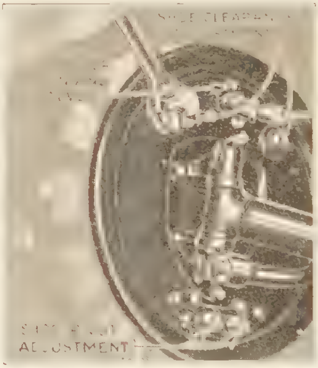


Figure 136

Figure 135.—Foot lever adjustment

Figure 136.—Adjusting Lockheed internal brakes

2255. A pedal can be adjusted for clearance by adjustment No. 1, shown in Figure 135, provided that the foot lever has sufficient clearance under the floor board. If the foot lever is already close enough to the floor board, make clearance adjustment as shown by adjustment No. 2.

2256. If it should ever be necessary to tighten adjustment No. 1 to obtain clearance at the floor board, be sure to shorten the connecting tube at adjustment No. 2 so as to restore the ½-inch free pedal movement.

2257. Jack up a wheel and turn one of the adjusting screws, shown in Figure 136, until the brake shoe binds against the drum. Then, loosen the screw just enough so that shoe does not bind. Repeat this procedure on all of the adjusting screws. The screws are self-locking; they remain in whatever position they are left by the wrench.

2258. There are eight of these screws, two on each wheel. Their function is to move a cam which regulates the position of the shoe in regard to the drum. They are arranged so that when a wrench is on them with the handle straight up, turning the wrench toward the wheel rim will bring the shoe closer to the drum.

2259. Fluid leaks are rare. They can take place at the pipe connections or at a wheel cylinder. To test for them, carefully clean mud from all of the pipe connections shown in Figure 131. Then, apply the brake pedal as hard as possible and block it in this position. After waiting a few minutes with the brake set, examine the connections for leaks. If no leaks appear, release the brake pedal and remove a wheel. Then, remove the rubber boots from the ends of the wheel cylinder. If the removal of a cup releases more than a teaspoonful of liquid, the wheel cylinder should be removed and reconditioned. The Wagner Electric Corporation branches have an exchange plan whereby an old cylinder can be reconditioned at nominal expense. However, little trouble is given by the wheel cylinders, provided that genuine Lockheed fluid is used in the system.

2260. When some hydraulic connection has been broken, or a wheel cylinder is removed, or the supply tank fluid is permitted to get low, or a wheel piston is forced out of its cylinder by applying the brake with a wheel removed, air will get into the brake system and seriously interfere with its operation. The interference is due to the fact that air is compressible, whereas the fluid is not. The result is that when the brake pedal is depressed, it simply compresses the air instead of building up pressure in the fluid to apply the brakes.

2261. Air can be removed from the system by bleeding, as follows: First fill the supply tank with fresh fluid. Then remove the cap screw from the bleeder valve and screw in the bleeder drain tube, as shown in Figure 137. The connection into which the bleeder drain tube is screwed is also a valve. After the tube is screwed in place, open this valve by unscrewing three-quarters of a turn. Then, place the end of the drain tube in a suitable receptacle and depress the brake pedal by hand. Allow the brake pedal to return and repeat the operation. Ten depressions are required to bleed each wheel cylinder. Do not put the old fluid back into the supply tank.

Figure 137.—Bleeding Lockheed brakes

2262. When bleeding, be sure to keep the master-cylinder supply tank more than half full of fluid; otherwise, air will be drawn into the system at this point, necessitating re-bleeding. After bleeding a cylinder, close the valve tightly with a wrench and replace the cap screw. After all wheel cylinders are bled, refill the supply tank with fresh fluid and replace the filler plug. See that the filler plug is tightened securely.

BENDIX BRAKES

2263. Bendix three-shoe self-energizing brakes (Figures 138 and 145), are used on a number of cars. The adjustment described fits the 1928 Essex particularly but may be applied in a general way to other cars with these brakes:

2264. Front Wheels: Turn square ball nut *2* until contact point of ball on crank with cam lever is $1/16$ inch behind the center of steering king pin with brakes released. Loosen lock-nut in cam lever adjustment *1* and adjust the screw away from the ball until the brake shoes are free. Loosen eccentric lock-nut *3* and turn eccentric in same direction wheel revolves when car moves forward till brake is tight against drum. Back off gradually till wheel is just free. Hold eccentric and tighten lock-nut. Tighten lever adjusting screw *1* against ball till brake binds, then back off till wheel is just free. Tighten lock-nut.

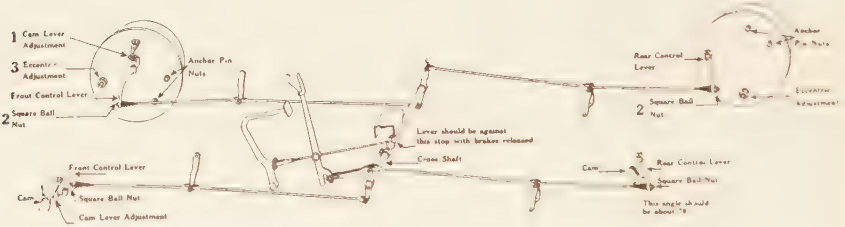

1 Cam Lever Adjustment
3 Eccentric Adjustment
Frout Control Lever
2 Square Ball Nut
Anchor Pin Nuts
Lever should be against this stop with brakes released
Cross Shaft
Front Control Lever
Cam
Square Ball Nut
Cam Lever Adjustment
Rear Control Lever
Anchor Pin Nuts
2 Square Ball Nut
Eccentric Adjustment
Cam
Rear Control Lever
Square Ball Nut
This angle should be about 70

Figure 138.—Bendix brake system. The pedal acts on all four wheels; the hand brake acts on the rear wheels

2265. Rear Wheels: Angle of center lines, with brake rod should be about 70 degrees, with brakes released, otherwise reset as follows: Loosen clamp bolt and slide lever off serrations. Slack off square ball nut *2* to end of thread on rod. Apply brake with Stillson wrench on camshaft and slip control lever on serrations. If brake is too tight, move lever back one serration. Tighten clamp bolt. Control lever should form approximately the same angle with the rod on both brakes. Take up square ball nut *2* till wheel just drags. Back off until wheel is just free.

Equalizing: Equalize as follows: Push pedal down with block or jack until the tightest wheel can just be turned by hand. Slack off tight wheels a half turn at a time till all four are the same. Remove block from pedal and try all four wheels for drag. There should be no drag if previous operations were done properly.

2266. Major Adjustments: Anchor pins should be adjusted only, (a) When fitting newly lined shoes. (b) When anchor pin nuts are found loose. (c) When other adjustments fail to give satisfactory results.

To adjust anchors: Turn eccentric adjustment *3* away from articulating pin and leave loose. Slacken tight anchor pin nuts free of lock washers. Tap both anchors out against drum. Hold brake on tight by equivalent of a 100-pound load on the end of an 8-inch Stillson wrench on control shaft, or same length monkey wrench on control lever. Tap anchor pins on end and try to turn wheel forward with brake applied. Still holding brake on, tighten both nuts as tight as possible with a 16-inch wrench. Release brake; then adjust eccentric and make other adjustments as previously described.

Where the brake drums are slotted so that feeler gages may be inserted between the shoe linings and the brake drums the adjustments may be checked as follows:

Remove covers on slots. Check toe and heel of auxiliary shoe and toe and heel of secondary shoe with feelers. Both ends of the shoe should be alike within 0.002 inch. If not to these limits, repeat anchor adjustment or loosen improperly set anchor one turn and tap until correct clearance is obtained. Then tighten firmly. Replace covers on slots.

BENDIX TWO-SHOE BRAKE

2267. The Bendix Brake Co. recently brought out a 2-shoe brake in addition to its 3-shoe braking system, previously described. The self-energizing principal is employed that is, when the brake pedal is compressed the rotation of the brake drum assists in applying the brake shoes, as shown in Figure 139.

The primary shoe is not anchored. It hinges freely by means of an articulating pin to the floating end of the secondary shoe. When the brake is applied, the rotating drum tends to drag the primary shoe around with it, and this action applies the secondary shoe (rotating the entire assembly of break shoes tighter and tighter against the break drum as the pedal pressure is increased).

Figures 140 and 141 show a typical installation as used on the Studebaker Dictator models FC and GL. The mechanism used on many other cars employing this system is similar, but not identical. The adjustment is as follows:

A. Loosen lock-nut on eccentric adjustment *1*. This adjustment centralizes the shoes. Turn eccentric in direction wheel revolves when car is

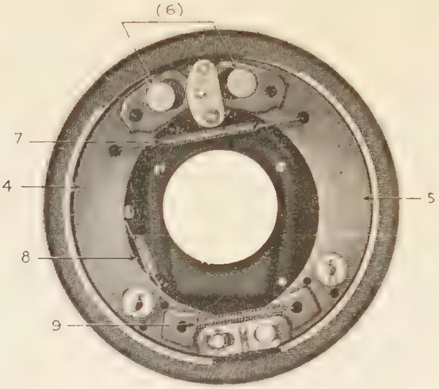


Figure 139.—Bendix 2-shoe brake; inside view of left front brake:

4—Primary shoe
5—Secondary shoe
6—Anchor pins
7—Primary and secondary shoe return spring
8—Primary shoe return spring
9—Spring for lower end of primary and secondary shoes

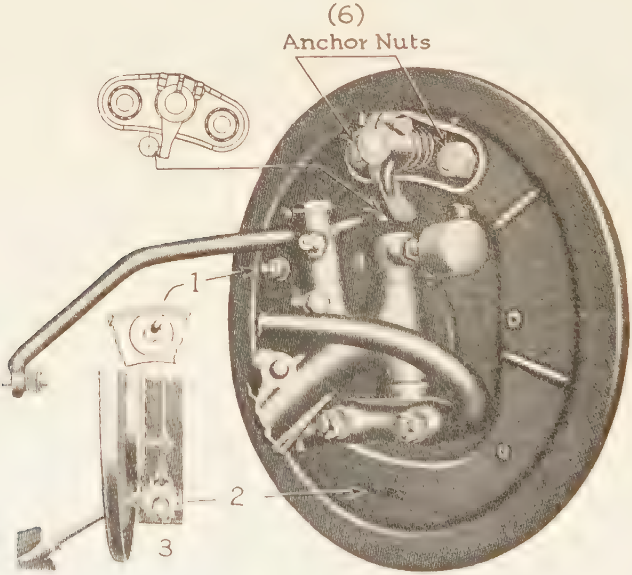


Figure 140.—Bendix 2-shoe brake. The center of the ball on the front control lever should be over the center of the king pin in the steering knuckle when the brake hook-up is in the "off" position, and there should be a very slightly felt "back lash" between the ball and the lever. There should be a similar back lash in the rear control levers

moving forward, until a very slight brake drag can be felt when turning wheel over by hand. Then turn eccentric in opposite direction until wheel is just free of brake drag. Tighten lock-nut. Make this adjustment at each of the four wheels.

B. Remove cover plate *2* and with a screwdriver or other suitable tool, turn the notched wheel *3* of the adjusting screw toward the rim of the backing plate, until a very slight brake drag can be felt when turning wheel over by hand. Then turn back the adjusting screw *3* until wheel is just free of brake drag. Make this adjustment at each of the four wheels.

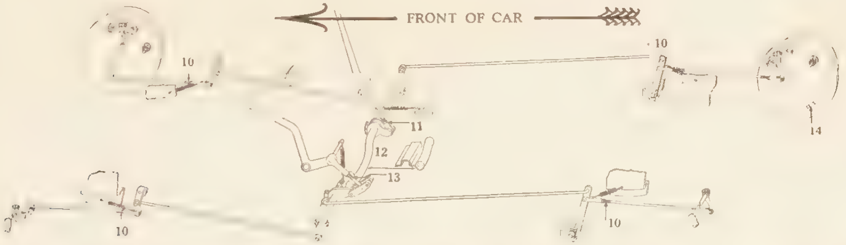


Figure 141.—Bendix 2-shoe brake linkage as used on some Studebaker models. Note the following adjustments:

10—Adjust control lever position here
11—Adjust hand lever here to permit ½-inch back lash at hand end
12—Make sure that cross shaft returns to stop as illustrated
13—Adjust at this point until all back lash is removed
14—Always replace this cover plate on each of the four wheels.

C. With car still jacked up, apply brakes by depressing foot pedal approximately two inches, using a pedal jack or other suitable means to hold the pedal in this fixed depressed position. Try the brake holding effect by pulling wheels over by hand. All wheels should be alike. If not, then turn (loosen—not tighten) the adjusting screw *3* on the tighter wheels until the brake drag is the same on all wheels. Then replace the adjusting screw hole cover plate, remove pedal jack, and let car down off car jacks.

CABLES IN PLACE OF BRAKE-RODS

2268. Recently, the Bendix Brake Co. introduced a unique cable mechanism to replace completely the customary brake-rod assemblies running to the four wheels. Both the pedal and the hand lever operate a full-floating brake cross shaft which in turn rotates a double bell crank at either end. To each end of each bell crank it attached a cable which runs along the frame to a point where it enters a flexible tube, through which it passes to the lever which rotates the cam which expands the brake. The tube is made of a specially-designed, heavy coiled spring, fabric covered and filled with grease. The tube, of course, provides a "constant length" for the cable, regardless of road wheel position. This new system eliminates all lubrication points and possibility of rattles. Two fundamentals made this new design possible. The cable is a new non-stretch type wherein each of the 51 strands is first formed to the shape it will later occupy in the cable, and therefore when the strands are assembled the customary stretch is avoided. The other feature which permits a full cable actuation is the development of a welding process for attaching the cable to the yoke at each end which absolutely eliminates any danger of loosening.

BRAKE RELINING

2269. It is advisable to have a repairman reline your brakes. However, if you wish to do the work yourself, buy a good grade of lining, leaving the size of lining and the length to be determined by the man from whom you buy it. It is advisable to check the lining for length, width, and thickness at the car before driving away. Count the number of rivets in the band (assume the same number for the shoe) and buy split rivets of a length recommended by the salesman; obtain at least a dozen more than required—better to have rivets too long than too short. If in doubt, buy rivets ¼ inch longer than the combined thickness of new lining and brake band or new lining and brake shoe. On cars equipped with Bendix, internal Lockheed, or Steeldraulic, the old shoes should be exchanged for relined shoes.

2270. Jack one wheel up securely and remove it as described in paragraph 2105 if it is a rear wheel, or paragraph 2404 if it is a front wheel. Disconnect the brake band or the shoe as the case may be and cut off the old rivets with a hammer and cold chisel, and remove the old lining. Measure the length of new lining, by laying the old on it, and cut the new lining with a hacksaw, or a hammer and cold chisel. Use the brake drum as an anvil, placing the lining on the band or shoe and putting it back on the drum. If possible, clamp the band or shoe in place by pulling on the actuating lever just as though you were applying the brake; otherwise clamp the lining in place on the band or shoe, using screw clamps and rivet, or use the closed jaws of a vise as an anvil.

2271. Rivet each end first and then rivet from each end toward the center. The head of the rivet should be on the back of the band or shoe and the split ends of the rivet on the face of the lining against which the brake drum rubs. Start each rivet carefully and then drive it home with two or three medium blows. The rivet should spread automatically, the two points pointing in opposite directions. It is possible that the first two or three rivets will be spoiled and will have to be pulled out, but after that sufficient skill should be acquired to drive the rivets satisfactorily. The bent-over points of the rivets should lie flush with the face of the lining, and if they do not, they should be hammered, being careful, however, not to change the roundness of the band or shoe.

2272. After the job is finished, replace brake and wheel, and after both wheels have been finished, adjust brakes as described in paragraph 2214. After a few hundred miles, when the lining has worn in, an additional adjustment will be required.

BRAKE CARE AND TROUBLES

2273. Following is a series of questions and answers which cover all general points concerning brake care and brake troubles.

FRICTION

2274. *What is friction?*

Friction between any two surfaces (Figure 142), is due to the resistance offered by the irregularities, which are present even in surfaces which look perfectly smooth to the eye.

Looking at this surface still more closely (Figure 143), when one "mountain" slides over another, each is bent out of shape temporarily, its normal form being shown by the dotted lines. This bending action produces heat, just as bending a wire vigorously with the fingers makes the wire hot at the bend. As these microscopically rough surfaces rub over each other, wear results because the bending action is often so severe as to break off some of these mountains. If big mountains are broken off, rapid wear results; whereas if merely ridges on the surfaces of the big mountains are broken off, normal wear occurs.

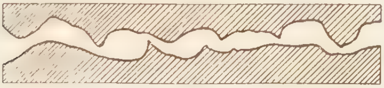


Figure 142

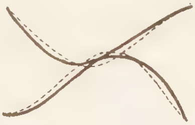


Figure 143

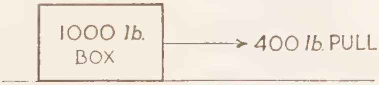


Figure 144

Figure 142.—Illustrating friction between two smooth surfaces

Figure 143.—Illustrating sliding friction

Figure 144.—Illustrating coefficient of friction

2275. *What is coefficient of friction?*

The friction between any two surfaces obviously depends on the character of the surfaces and also on the pressure holding them together. (Figure 144). Coefficient of friction is defined as the ratio between: (1) The pull required to move one surface over another and (2) The pressure holding these two surfaces together. Examples: (1) If it requires 400 pounds to pull a 1,000-pound box over a cement floor, the coefficient of friction is 400/1,000 or 0.4. (2) If the weight on one wheel is 750 pounds and a force of 350 pounds acting at the circumference of the tire is required to lock the wheel, then the coefficient of friction between the wheel and the road is 350/750 or 0.466. (3) If a pressure of 10 pounds on a small piece of brake lining held against a drum exerts a retarding force of 3½ pounds, the coefficient of friction is 3½/10 or 0.35. Cold grease and cold soap increase the coefficient of friction between lining and drum while dirt, kerosene, water, warm grease and warm soap decrease the coefficient, the brakes becoming more effective in the first case and less effective in the second case.

2276. *What effect has grease?*

Increases effectiveness of braking action when drum is cold, and greatly reduces braking power with warm drum. If the presence of grease is discovered almost immediately it may be washed off with gasoline but otherwise it is advisable to reline inasmuch as burning out the grease with a torch is rarely a permanent remedy and usually harms the lining.

2277. *What effect has soap?*

Soap increases effectiveness of braking action when drum is cold and greatly reduces it when warm. Caused by careless washing. Trouble usually appears on only one wheel. Try burning it off by operating car with brakes on just below smoking point for a few hundred feet. If trouble reappears, repeat treatment. If trouble comes back after third treatment, lining must be replaced.

2278. *What effect has kerosene?*

Kerosene reduces brake effectiveness whether drums are hot or cold. Due to careless washing. Only permanent remedy is relining although effectiveness may be temporarily improved by running car in second for a few hundred feet with brakes applied just below the smoking point.

2279. *What effect has moisture?*

A very thin film of moisture such as obtained when a car is allowed to stand in a damp atmosphere greatly increases the effectiveness of the brakes but the moisture disappears and the brakes become normal after a few applications. The increased effectiveness is assumed to be due to the "sucking action" of the lining against the drum, that is, the film of moisture squeezes out the air between lining and drum so that the pressure of the atmosphere is added to the pressure applied by the driver.

2280. *What effect has water?*

A film of water on the brakes reduces their effectiveness by acting as a lubricant, effectiveness being reduced as the thickness of the film increases. Water may be eliminated by operating the car with the brakes on until it has evaporated. Some linings are more seriously affected by water than others, and it is said that a lining which repels water is affected less than a lining which attracts water permitting it to spread out in a film. Improved brakes with any wet lining may be secured by reducing the clearance and shaping the band to prevent formation of water pockets.

2281. *What is a self-energizing brake?*

The band or shoe assembly is so designed that it tends to apply itself when assisted by the brake pedal, common types of self-energizing brakes being shown in Figure 145. Generally speaking, self-energizing brakes are designed to work best with a lining having a given coefficient of friction.

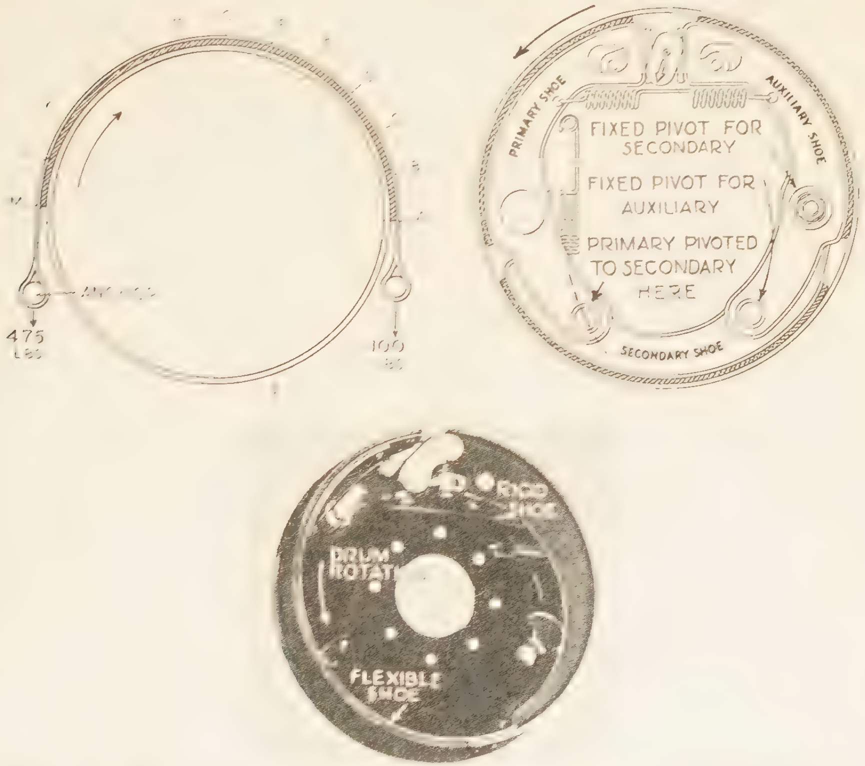

475
LBS
100
PRIMARY SHOE
AUXILIARY SHOE
FIXED PIVOT FOR SECONDARY
FIXED PIVOT FOR AUXILIARY
PRIMARY PIVOTED TO SECONDARY HERE
SECONDARY SHOE
RIGID SHOE
DRUM ROTAT
FLEXIBLE SHOE

Figure 145.—Self-energizing brakes. In the diagram: Braking effect is proportioned to pressure between band and drum. With drum stationary, pressure is proportional to pull on band. When drum rotates, the pull at B is greater than the pull at A because of the frictional pull between A and B. Similarly the pull at C is greater than the pull at B, etc. It can be shown by calculation that if the coefficient of friction is 0.5 and the pull at A is 100 pounds, the pull at M must be 475 pounds for a band which wraps around half the drum. Since the pressure increases progressively from A to M, the retarding force which the band exerts on the drum increases progressively from A to M, and thus supplies much greater braking effort than would be the case if the action were not present. To secure the same retarding force without this effect would require very much more than 100 pounds pull on the band. Obviously much less pedal pressure is required for a given degree of braking action when a wrapping brake is used

2282. Therefore if a lining of a higher coefficient of friction is applied the brakes may grab even to the point of locking the wheel whereas if the friction coefficient is too low pedal pressure may be objectionably high. In the case of some two-shoe internal brakes, if a higher coefficient lining is used, the brake may lock unless it is cut back at the ends as shown in Figure 146, the amount being determined by experiment or experience.

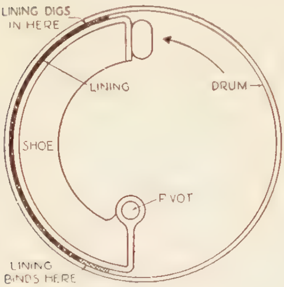


Figure 146.—How a brake may lock

2283. *What is glazed lining?*

Caused by charring of the lining. It reduces the effectiveness of the brakes. Often a lining is diagnosed as "glazed" when it is not glazed but possesses one of the following defects: (1) Lining is coated with half-dry grease often difficult to detect; (2) Road grit or rust from the drum becomes embedded in the lining reducing brake efficiency 30 or 40 per cent; (3) If rivets are in contact with drum (but not in sufficient contact to cause scoring), lining fails to make perfect contact with drum, and the trouble is diagnosed as "glazed lining."

2284. *What makes brakes weak?*

If weak when both hot and cold, brake trouble is due to rusty linkage, linkage needs lubrication, front axle has slipped back, worn lining, glazed lining, drum rust, metal particles or road grit on lining, drums scored, rivets just touching drum, kerosene, lever positions incorrect; while good brakes when cold but poor brakes when warm are caused by grease or soap on lining.

2285. *What makes brakes drag?*

A band may be out of round or broken or weak return springs, rusty brake linkage, linkage needs lubrication, full release of linkage prevented by some obstructing part on chassis, bent linkage.

2286. *What makes brakes grab?*

See next paragraph.

2287. *What makes wheel lock at same point every time?*

The brake drum is eccentric. If a car is equipped with internal self-energizing brakes a drum eccentricity of as little as 0.01 inch may cause this trouble. The remedy is to turn down the drum while mounted on its wheel on a suitable lathe.

Try brakes when cold and note if wheel locks. Then put car in second and run for several hundred feet with brakes just below smoking point. If locking tendency disappears, the lining is coated with *grease* or *soap*. If wheel locks both hot and cold the trouble is not at the braking surface but is external to it; however, see paragraphs 2281 and 2282. It causes includes improper anchor adjustment, rust in linkage, and particularly rust in equalizers, tight shaft, etc., weak pull back spring on one side of equalizer, excessive play in spring eye at front end of rear spring or worn rubber or rubberized fabric shackle at this point, or loose spring clips or sheared spring center bolt.

2288. *What makes brakes squeak?*

Squeak has a higher-pitched sound than *chatter*. It is due to drum vibration and this in turn has many causes. Adjust band or shoe to even clearance, and if band is out of round, reform it. Thoroughly lubricate brake linkage with penetrating oil to remove "rusty hinge" squeaks. Other causes of squeaks and their remedies include: (1) Eccentric drum, turn down or replace. (2) Rough drum, turn down or replace. (3) Equalize brakes. (4) Grit on lining, flush lining with water or clean with wire brush and if necessary replace lining. (5) Adjust external brakes to give good working contact for a few inches either side of anchor bracket with reduced pressure on remainder of band. (6) See that brake is free at anchor bracket, and that anchor bracket is securely mounted. (7) Reset rivets to $^{1}/_{16}$ inch below lining surface. (8) Reline, bearing in mind that a softer lining usually is less likely to squeak. (9) Insert a hacksaw blade shim near each end of the brake band, or two blades at each end if the lining is very thick. This repair should prove effective until high spots produced by shims have worn down. (10) If drums are thin, replace. Some brakes may squeak in a moist atmosphere as on a foggy night.

2289. *What causes chatter?*

Chatter has a lower-pitched sound than a squeak. Improper band or shoe support is the first thing to look for. Chatter will result if anchor bracket is broken or if band is loose on anchor bracket, if bracket is loose on dust shield, if dust shield is loose on axle, if axle is loose on spring, or if worn spring bolts, or worn rubber or fabric shackles permit undue lost motion. Other causes of chatter include badly worn linkage, lining loose on rivets, loose wheel bearing, eccentric drum or sticky lining. If chatter occurs with cold brakes but disappears with warm brakes the lining is sticky. For remedy see *grease* and *soap*. Chatter may occur if brake mechanism forces end of band into drum as shown in Figure 147. The remedy is to reduce adjustment on band and take up adjustment on linkage until pull is tangential.

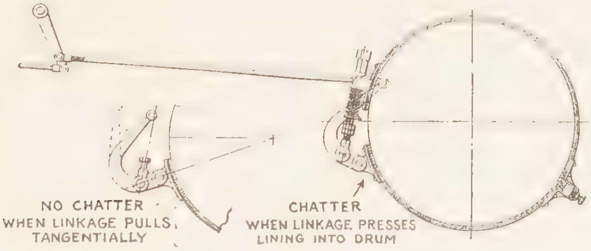

NO CHATTER WHEN LINKAGE PULLS TANGENTIALLY
CHATTER WHEN LINKAGE PRESSES LINING INTO DRUM

Figure 147.—Cause of brake chatter

2290. *What causes brake lining to burn after adjustment?*

If it burns on top with external brake or on bottom with internal brake, the cause is wheel bearings in need of adjustment.

2291. *What causes rapid wear?*

Scored drums. Turn down drums but minimum thickness is 1/8 inch and even then squeaks or a spongy pedal may result.

2292. *Do you know these tips about relining brakes?*

Do not crowd lining too much when applying it to band or shoe. After brakes have been relined and adjusted, run car for a few hundred feet in second gear with brake applied just below smoking point. Then readjust brakes if necessary.

THE LEVER

2293. *Explain the principle of the lever?*

In studying both brake equalizers and bell-crank and pull-rod assemblies, an understanding of the principle of the lever is desirable. Regardless of the point at which the lever is pivoted, the force required to overcome a given resistance may be stated as follows: Force in pounds times the length of its lever equals resistance in pounds times the length of its lever. As indicated in the following examples (Figure 148A-H):

A—Force x 4 inches equals 100 x 2 inches. Force equals 50 pounds.

B—Force x 3 inches equals 100 x 1 inch. Force equals 33.3 pounds.

C—Force x 1 inch equals 100 x 3 inches. Force equals 300 pounds.

D—An irregular lever does not change the situation. In both of these cases: Force x 2 inches equals 100 x 1 inch. Force equals 50 pounds.

E—The force must always be considered as acting at right angles to the pivot, as shown by the dotted line in this case, and the distance used in the calculation is the length of the dotted line, thus:

Force x 1.14 inches equals 100 x 1 inch.

Force equals 100/1.14 or 87.7.

F—Similarly, Force x 0.94 inch equals 100 x 1.88 inches. Force equals 1.88 x 100/0.94 equals 200 pounds.

G—Maximum torque on shaft is secured when pull rod is at right angles to bell crank. Then torque = 5 x 100 = 500 pound-inches.

H—On the other hand, if the bell crank makes an angle of more or less than 90° with pull rod, torque is reduced. In the diagram shown,

Torque = 4 x 100 = 400 pound-inches.

2294. *When is linkage correctly adjusted?*

Before brakes may be properly adjusted, the linkage from pedal to brakes must be in proper relation. It may usually be assumed that the linkage is correctly set at the factory and therefore should need no adjustment unless it has since been tampered with. The setting of the linkage should not be changed when adjusting brakes unless it is found to be incorrect. With brakes released, the angles which the various bell cranks make with their pull rods varies considerably on different chasses and no general rule concerning these angles can be given. On the other hand, with few exceptions, it is true that when the brakes are fully applied all bell cranks should stand at right angles to their pull rods since maximum braking power is then realized. As shown by the illustration the torque applied to the shaft, assuming a 100-pound pull and a 5-inch crank, is 5 x 100 or 500 pound-inches, whereas if the bell crank stands at such an angle that the perpendicular distance, as shown by the dotted line, is only 4 x 100 or 400 pound-inches, consequently the braking effort is only 400/500 or 80 per cent of what it is with the bell crank at right angles to its pull rod.

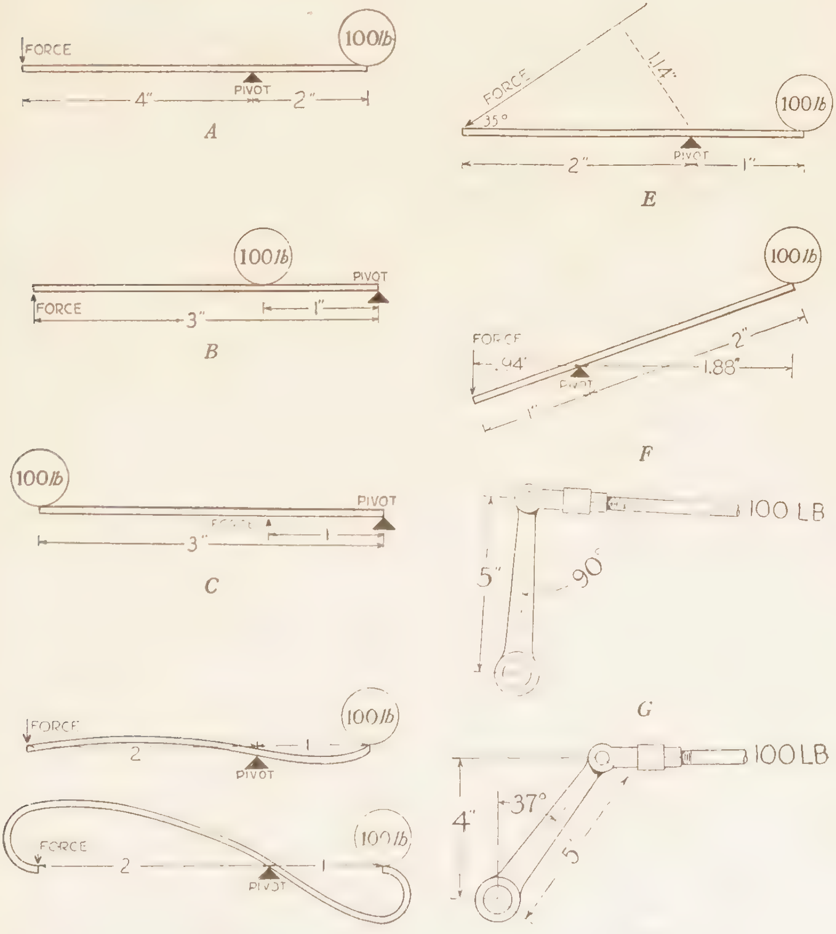

FORCE
100 lb
PIVOT
4"
2"
A
FORCE
35°
1.1/4"
100 lb
PIVOT
2"
1"
E
100 lb
PIVOT
FORCE
3"
1"
B
100 lb
FORCE
.94"
2"
1.88"
PIVOT
1"
F
100 lb
PIVOT
FORCE
3"
1
C
100 LB
5"
90°
G
FORCE
100 lb
2
1
PIVOT
FORCE
100 lb
2
1
PIVOT
D
100 LB
37°
4"
5"
H

Figure 148, *A, B, C, D, E, F, G, H*.—Illustrating principle of the lever

Chapter XX

STEERING MECHANISM

2301. From a practical standpoint there is nothing to be gained by describing the construction of various steering gear mechanisms, therefore the discussion will be limited to their lubrication, care, and adjustment.

2302. The adjustment of three types of steering gears in common use will be described, and if examination of your steering gear proves that it is totally different from these three types, the adjustment should be left to an experienced man—such a case will be rare, however.

STEERING GEAR ADJUSTMENT

2303. Most steering gears have an adjustment as indicated in Figure 149, at the top of the steering gear housing. Invariably, this nut is locked by a clamp bolt or some other obvious locking device, as for example, the locking plate and set-screw arrangement in Figure 150. If there is doubt as to which is the adjusting nut (when there are more than one), the locking device should give a clew. After the locking device has been loosened or removed, the nut is turned down (clockwise) to decrease the play in the steering gear, as described in paragraph 2318. In a few cars the adjusting nut (or collar) is placed at the base of the steering gear housing.

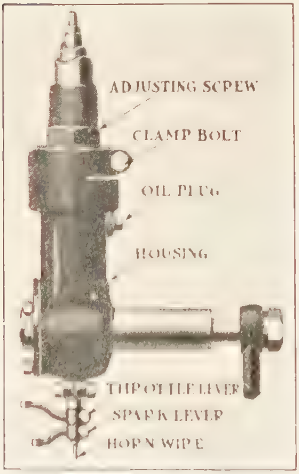


Figure 149.—Typical steering gear mechanism

2304. On steering gears with a circular housing tangential to the cylindrical housing (Figure 150), there are two or three additional adjustments. If adjusting the nut on the top of the housing does not reduce the play measured on the steering wheel rim to less than one inch, adjust the screw, nut or collar, to be found at the center of the circular housing adjacent to the engine (Figure 151). The locking device, of course, must be released before this adjustment can be made. Turn the adjustment to the right, as far as possible, and then back off a fraction of a turn, or until the steering gear does not bind when the steering wheel is moved. If play is still excessive, remove steering arm from steering gear shaft, and turn steering wheel until steering gear shaft has moved one-quarter revolution. Then connect the steering arm to the shaft again. If play is still excessive, the steering gear must be removed and the eccentric bushing in which the steering shaft is mounted must be turned to bring the worm gear into deeper mesh with the worm pinion. Inasmuch as it is advisable to have an experienced man make this latter adjustment, no further details will be given.

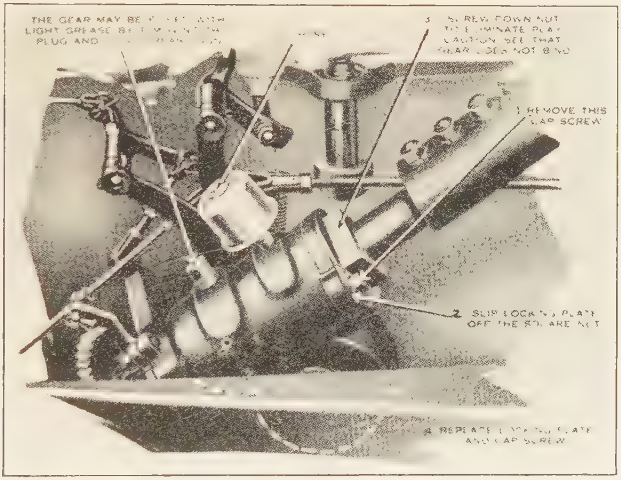

THE GEAR MAY BE [illegible] WITH
LIGHT GREASE BY [illegible]
PLUG AND [illegible]
3 SCREW DOWN NUT
TO ELIMINATE PLAY
CAUTION SEE THAT
GEAR DOES NOT BIND
1 REMOVE THIS
CAP SCREW
2 SLIP LOCKING PLATE
OFF THE SQUARE NUT
4 REPLACE LOCKING PLATE
AND CAP SCREW

Figure 150.—Worm and wheel steering gear

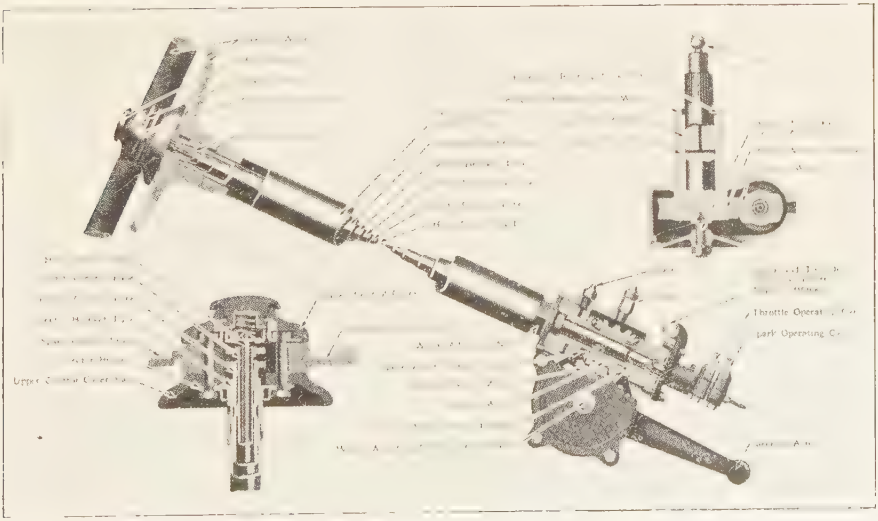

Throttle Operat
park Operating C

Figure 151.—Details of worm and wheel steering gear

CAM-AND-LEVER GEAR

2305. The cam-and-lever steering gear (Figure 152), is a popular type: There are two adjustments. There are shims between the steering gear housing and the cam thrust nut. To correct excessive end play of the cam, loosen the clamp screw, unscrew the cam thrust nut a few turns, and remove one of these shims. Screw the thrust nut back securely in position and lock it with the clamp screw. The second adjustment is provided between the cam lever and the cam by means of shims between the cam lever shaft case assembly and the steering gear housing. To correct excessive lost motion between the cam lever and the cam, loosen the cam lever shaft case assembly and remove a shim. This adjustment must be made with the steering gear at its mid-position of travel because this is its tightest point on the cam, and the adjustment should never be made so tight as to cause the steering gear to bind when going through this tight position. Failure to set the steering gear at its mid-position when the front wheels are directed straight ahead will result in a rattle between the cam lever and the cam.

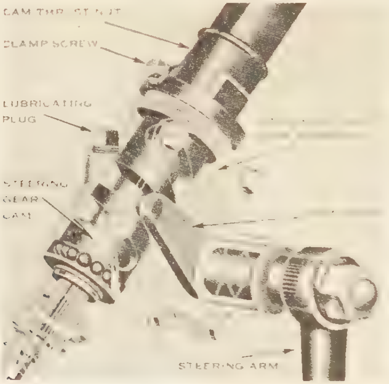


Figure 152.—Cam-and-lever steering gear on Stutz car

2306. The steering gear housing should be filled with grease every 2,000 miles, and grease cups or oil holes should be attended to periodically in addition.

2307. Excessive play in the drag-link may be removed by screwing in on the countersunk screw shown in Figure 153.

2308. Excessive play in the tie rod pins and bushings (Figure 154), may be removed by installing new pins and bushings, although the tie-rod shown in Figure 155 may be adjusted for wear, the same as the drag-link shown in Figure 153.

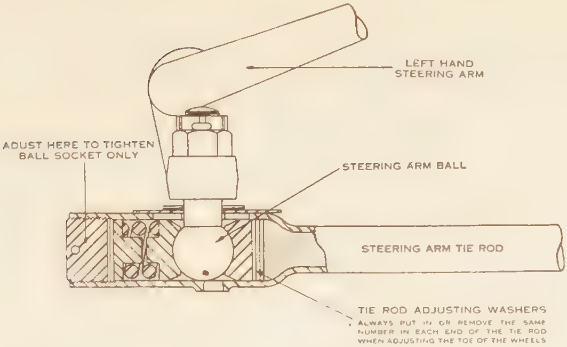

LEFT HAND STEERING ARM
ADUST HERE TO TIGHTEN BALL SOCKET ONLY
STEERING ARM BALL
STEERING ARM TIE ROD
TIE ROD ADJUSTING WASHERS
ALWAYS PUT IN OR REMOVE THE SAME NUMBER IN EACH END OF THE TIE ROD WHEN ADJUSTING THE TOE OF THE WHEELS

Figure 153.—Ball-and-socket construction on drag-link

2309. Excessive play in the king pins and bushings is usually removed by installing new pins and bushings (Figure 154), although on a few cars taper roller bearings, which are adjustable, are used (Figure 155).

2310. The front wheels should be $\frac{1}{16}$ to $\frac{3}{8}$ inch closer together at the front than at the rear, the figure varying with different cars. This is called toe-in. If the wheels do not toe-in the right amount, tire wear will be excessive.

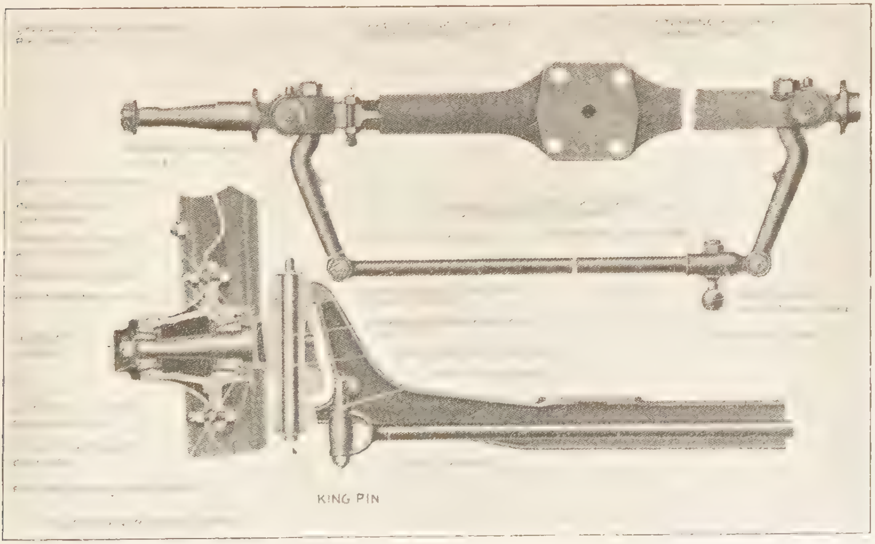


Figure 154.—Front axle construction

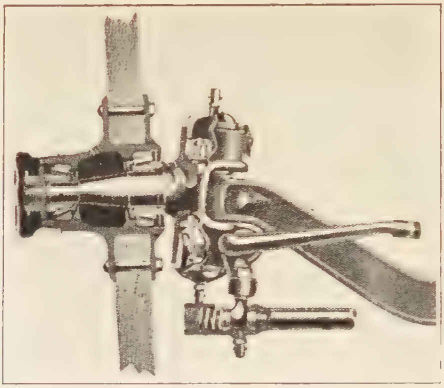


Figure 155.—Front axle construction with king pins on taper roller bearings and tie-rod equipped with ball-and-socket joints

HARD STEERING

2311. Symptoms—Steers hard.

2312. Causes—(1) Tires soft. (2) King pins and tie-rod bushings require lubrication. (3) Steering gear needs lubrication. (4) Steering gear adjusted too tightly. (5) Some part of steering gear mechanism bent, including front axle.

2313. Cure—1. Inflate tires.

2314. Cure—2. Lubricate these parts. If grease cups are used be sure that they are effective. If oil cups are used see that passages are not clogged with dirt.

2315. Cure—3. Lubricate steering gear by filling it with grease with a gun. In an emergency fill the grease cup on the gear and screw it down tightly. Repeat several times.

2316. Cure—4. If steering gear has just been adjusted, reduce adjustment.

2317. Cure—5. Examine all parts for alinement, and consult your repairman if any bent parts are found.

EXCESSIVE PLAY

2318. Symptom—More than one inch total play in steering wheel.

2319. Causes—(1) Steering gear requires adjusting. (2) King pins and bushings loose. (3) Tie rod pins and bushings loose. (4) Drag-link loose. (5) Other defects.

2320. Cure—1. Jack up front wheels by placing jack at center of axle. Note how much play is in steering gear housing by having someone watch the steering arm, while the steering wheel is turned slowly back and forth.

Note extent of motion possible without moving steering arm. If more than ½ inch, adjust steering gear as described in paragraph 2303. In doing this be sure that gear does not bind at the extreme right and left limits of steering wheel travel. If so, reduce adjustment. Be sure to lock all adjustments securely.

2321. Cure—2. After examining steering gear, inspect king pins and bushings. To do this, grasp each front wheel, top and bottom and shake it, and watch play between steering knuckle and axle. If more than a slight amount, bushings and pins should be replaced, or the bearings adjusted if adjustment is possible. In either case it is best to have an experienced man do the work.

2322. Cure—3. Grasp each front wheel at the sides and shake it, noting play in tie-rod pins and bushings. If more than barely perceptible, new parts should be installed unless adjustment is possible, as shown in Figure 155.

2323. Cure—4. Adjust drag-link (Figure 153), as described in paragraph 2307.

2324. Cure—5. See that the steering wheel is not loose on its shaft, that the steering gear is not loosely connected to the frame, and that the steering arm is not loose on its shaft. Tighten parts that require it.

STEERING MECHANISM STICKS

2325. Symptom—Steering gear sticks.

2326. Causes—(1) Lack of lubrication. (2) Adjustment too tight. (3) Breakage.

2327. Cure—1. Fill steering gear with grease using the gun, or fill grease cup several times.

2328. Cure—2. If steering gear has just been adjusted, reduce adjustment.

2329. Cure—3. If trouble is neither of the preceding items, drive cautiously until the trouble is found, as there is a possibility that some part within the steering gear has broken, and it may lock tight and cause an accident at an unexpected moment. Consult your repairman at the first opportunity.

FRONT WHEELS SHIMMY

2330. Symptom—Front wheels shimmy.

2331. Causes—(1) Spring clips loose. (2) Excessive play. (3) Various.

2332. Cure—1. Tighten nuts on front spring clips securely.

2333. Cure—2. If spring clip nuts are not loose, but play in steering wheel is excessive, see paragraph 2318.

2334. Cure—3. In addition to the foregoing there are many other defects which will cause shimmying, although the ones mentioned are the only common ones. If shimmying is not eliminated by Cures 1 and 2, take your car to a dealer selling this make and ask him to check all measurements affecting the front wheels, front axle, springs, tires, wheel balance, etc. See that tires are inflated to pressure recommended by the manufacturer.

WHEELS SCRAPE

2335. Symptom—Front wheels scrape frame.

2336. Cause—Stop screws require adjusting.

2337. Cure—Adjust stop screws at either end of front axle until wheels no longer touch frame when steering wheel is turned all the way to the right or the left.

Chapter XXI

FRONT WHEELS

2401. Most front wheels are mounted on two taper roller bearings (Figure 154), and the bearings are adjustable. In a few cars, two cup-and-cone ball bearings are used and these are also adjustable. As a rule, there is no adjustment on wheels occasionally equipped with annular ball bearings.

ADJUSTMENTS

2402. To adjust a front-wheel bearing, jack up the wheel, remove the hub cap, remove the cotter-pin, and draw up on the nut until the side play at the top of the wheel, when it is shaken is not more than 1/16 inch. Do not confuse looseness in bearings with play in king pin (paragraph 2319). After making the adjustment, spin the wheel to see that it runs freely, and note that it should come to rest with tire valve at bottom. If not, reduce adjustment slightly. An adjustment that is too tight will not only cause bearing wear, but if the car is driven at high speed for some distance the bearing may heat sufficiently to "freeze" and a serious accident may result due to the wheel locking suddenly.

2403. As a rule, the adjusting nut on the left wheel turns in a counterclockwise direction to obtain a tighter adjustment, whereas the nut on the right wheel turns in a clockwise direction. After adjustment, put the cotter-pin back and spread it carefully. To be safe, it is desirable to use a new cotter-pin, but be careful to use the correct size.

2304. To remove the wheel, remove hub cap, cotter-pin, and adjusting nut and then pull wheel off, using wheel puller if necessary, although the wheel may usually be removed without the aid of a puller.

LUBRICATION

2405. To lubricate front wheel bearings, force grease into bearings with a gun, or fill hub cap with grease and screw it on tight, or better yet, remove wheel and smear both bearings with grease, in addition to filling space between the two bearings with grease. It is advisable to wash bearings thoroughly with gasoline before lubricating, thus removing old grease, grit, and metal particles.

2406. For discussion of front wheel and bearing troubles, see paragraph 2114, concerning rear wheels.

Chapter XXII

SPRINGS

CAUSE OF BREAKAGE

2501. Nearly all spring breakage is due to failure to keep the nuts on the spring clips tight (Figure 156). Tighten these nuts at least once in 5,000 miles. If the threads are so badly marred that they can not be tightened, obtain new spring clips and nuts. If the front axle has been bent in an accident, examine spring clips when the axle is removed. If the axle receives a hard blow but not sufficient to bend it, tighten spring clips after 200 miles, and again at 500, and examine spring clips for signs of failure. The blow may have been sufficient to start a slight crack in the spring clips, and the need for frequent tightening will reveal the fact that they are failing and should be replaced.

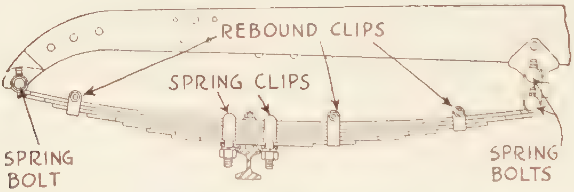


Figure 156.—Details of half-elliptic spring construction

2502. If the main leaf breaks, the spring will fail to support the car properly, although it is usually feasible to drive it slowly to the nearest town. If a stock spring of the right size is obtainable, it is generally best to have it put in rather than attempt to repair the old one, but if a stock spring can not be obtained, either through some repairman or through a dealer handling this make of car, the spring should be repaired. A blacksmith, specializing in spring repairs, will be found in most of the smaller towns, while there are spring repair specialists in most of the larger ones. The broken spring leaf can not be welded, but a new leaf must be made to take its place, and at the same time it is advisable to have the other leaves of this spring reset, as only in this way will all the leaves function together. The foregoing is orthodox information, but it should be added that there is reason for believing that a leaf may be replaced in any spring without resetting the spring; incidentally, this is standard Ford practice.

2503. If the car must be driven a long distance before a repair can be made, it is advisable to drive slowly to prevent further breakage. If the spring breaks in such a way that it fails to support the car properly it may be necessary to lash a block of wood of suitable size between axle and frame, although sometimes the spring may be patched up by placing an iron rod of suitable size along the spring as a splint, and then binding it securely with iron wire. These extreme measures are rare, however.

2504. If any leaf but the main leaf breaks, the fact may be more or less ignored, depending on the importance of the leaf. Tighten the spring clips to prevent further breakage. Bear in mind, however, that the breakage of the leaf has weakened the spring and that additional leaves will break sooner or later. It is advisable to install a new spring or have new leaves made to replace those broken, although this work may often be postponed for months, or until several additional leaves have broken.

2505. The breakage of a leaf is usually accompanied by a sharp and more or less loud report, and if the main leaf on a rear spring breaks forward of the axle, it will also be noted that the brakes may be very tight if the car drives through the springs; but this symptom will not ordinarily be noted if the car drives through a torque tube or radius rods.

2506. As the car grows old the springs are inclined to sag or set, especially if it has been subjected to rough roads, overloading or both. The springs may be reset by a competent spring repairman; but it is not advisable to have springs reset more than once. When a second resetting is required, buy new springs instead. Springs that have been reset more than once are likely to break.

2507. In rare cases, if springs are too weak, as indicated by frequent breakage and extreme flexibility, a leaf may be added to the spring by a competent spring repairman, the spring being reset at the same time, so that the new leaf will function in unison with the old.

2508. If springs are too stiff, as might be the case, in converting a touring car into a roadster, a leaf or two may be removed from each rear spring. It is advisable, however, to have this work done by a competent spring repairman, and have the springs reset at the same time.

2509. If the springs are exceptionally stiff, as just described, improved riding qualities may be obtained by the use of shock absorbers, balloon tires, or both. This remark, of course, applies to the older cars.

COMPRESSION AND REBOUND

2510. Shock absorbers are an essential feature of the modern car. Broadly speaking, there are two types in common use: "one-way" shock absorbers which reduce the severity of rebound (rebound is spring expansion following spring compression on a bump), and "two-way" shock absorbers which not only control rebound or spring expansion but also control spring compression. The following paragraphs explain shock-absorber action:

2511. Consider any spring, a long coil spring for example: If it requires 10 pounds pressure to compress it 1 inch, 20 pounds will compress it 2 inches, and 30 pounds 3 inches. Similarly, if 150 pounds are required to compress the rear spring of an automobile 1 inch; 300 pounds pressure will compress it 2 inches; 450 pounds, 3 inches and so on.

2512. Therefore, if a rear wheel rolls over a bump which compresses the spring 5 inches, the total compression pressure acting on the spring is 750 pounds. This large force pushes up on the body, accelerating the body rapidly upward, and jolting the passengers. By the time this force has spent itself, body and passengers have gathered considerable upward velocity. Then the body comes suddenly to rest but the passengers tend to keep on going—that is, they tend to leave their seats, and maybe hit the top. The action described in this paragraph is commonly called rebound.

2513. Similarly, in riding over a boulevard, suppose that spring deflections average ¼ to ½ inch, then the upward forces acting on the body will vary from 37.5 to 75 pounds, and uncomfortable jiggling of the passengers results.

2514. It is plain that a car would ride perfectly if this upward force were completely cancelled, but this is impracticable because the spring, once compressed, would then have no means of returning to its normal position. So we must compromise by cutting this upward force to such a small fraction that the upward accelerations it produces are no longer objectionable to the passengers, and yet we must not cut the spring force sufficiently to prevent it from returning rapidly to its normal position.

2515. To make this point clearer, assume that we add a one-way shock absorber, so designed that it requires 100 pounds to pull the strap out 1 inch, 200 pounds for 2 inches, 500 pounds for 5 inches. The pull of the strap opposes the force of the compressed spring, so that the net upward force acting on the body is now only the difference between the two—namely, when the spring is compressed 1 inch the upward force is now 50 instead of 150 pounds; when compressed 2 inches, it is 100 instead of 300 pounds, and so forth. The figures are the author's and are offered merely by way of illustration. Likewise, if the spring is compressed ½ inch, the net upward spring force instead of being 75 pounds, is only 25 pounds. Thus, whether the spring is compressed a large or small amount the shock absorber robs it of most of its force, and the residue remaining in the spring is insufficient to cause discomfort to the passengers. It should be noted, however, that few shock absorbers are ideally effective.

SHOCK ABSORBERS

2516. Fundamentally, in a two-way shock absorber which is also designed to control spring compression, the control of spring compression is not primarily to soften jolts. On the contrary, control of spring compression is for the purpose of preventing the axles from hitting the frame on severe bumps, and of course to this extent it suppresses jolts.

2516A. In all shock absorbers designed to reduce the force of spring expansion or compression the force absorbed by the shock absorber is accomplished by frictional action in the device, the friction turning to heat which is radiated from the instrument, consequently, the temperature of a shock absorber after traveling a rough road is a rough indication of how effectively it is working, the higher the better.

2516B. There are two fundamental types of shock absorbers, one in which a frictional lining is used, and the other is the hydraulic type in which oil or glycerin is forced through a small hole by the shock absorber, the resistance offered by the oil flowing through the hole being used to control the springs.

WATSON STABILATOR

2517. Figure 157 shows the construction of the Watson stabilator. Within the weatherproof housing, which is placed on the car frame, is a brake drum on which is mounted a specially prepared friction lining. This is attached to the upper end of the strap which runs to the axle. When the car spring is compressed, the axle moves closer to the frame, and strap and lining are moved anti-clockwise under the action of the hook on the eccentrically shaped ring which is fastened to the free end of the flat spiral spring. The brake drum is made in two halves with a slot between the two, wide

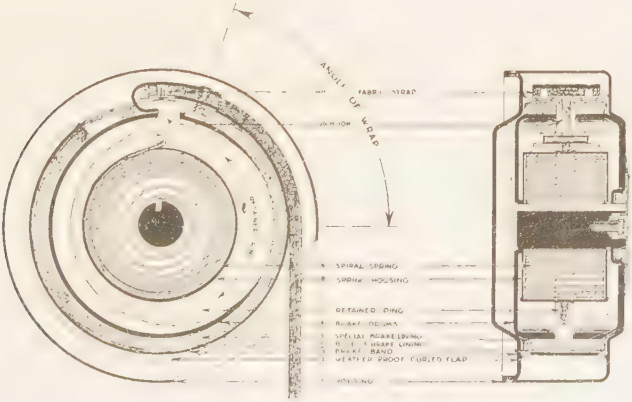


Figure 157.—Watson rubber-flow stabilator

enough to allow the hook mentioned to extend through as shown. The spiral spring has ample power to keep the strap taut, regardless of how rapidly the axle bobs up and down, therefore the action of the device is sufficiently rapid for all road conditions.

2518. The "braking action" of the device is proportional to the angle of wrap between the strap and the "brake lining" (Figure 158). In other words, the more the car spring is compressed, the closer the axle moves to the frame, the further the strap and lining are pulled anti-clockwise by the spiral spring, and the greater the wrapping angle as shown in the diagram. With this construction when the spring is slightly compressed the strap opposes the car spring force with only a small force; when the spring is greatly compressed it opposes with a large force because the angle of wrap is much increased.

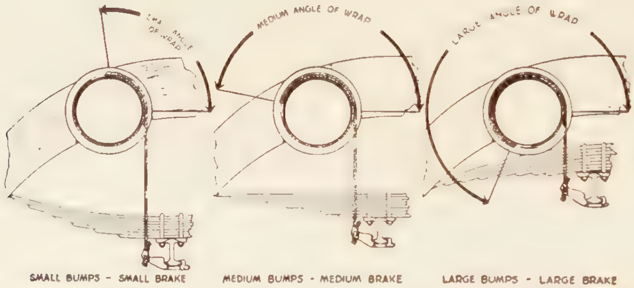

SMALL ANGLE OF WRAP
MEDIUM ANGLE OF WRAP
LARGE ANGLE OF WRAP
SMALL BUMPS - SMALL BRAKE
MEDIUM BUMPS - MEDIUM BRAKE
LARGE BUMPS - LARGE BRAKE

Figure 158.—Diagram showing action of Watson rubber-flow stabilator

2519. The spiral spring is contained in a cylindrical box of sheet metal filled with grease for indefinite lubrication; no other parts of the stabilator require lubrication; the brake lining is a specially developed material which is both fully effective and noiseless. The back of the brake lining is provided with a rubberized fabric band with edges which curl up against the sides of the stabilator housing, thus rendering it weatherproof. All metal parts, including enameled parts, are rust-proofed by the Parker process.

2520. Watson front shock absorbers are smaller than the rear ones because they must have a stiffer action as front springs are invariably much stiffer than rear springs.

HYDRO-CHECK SHOCK ABSORBER

2521. Figure 159 shows the internal mechanism of the Hydro-Check shock absorber, a one-way device made by the Continental Motors Corp., Detroit, Michigan. When a wheel rolls over a bump, the leaf spring is compressed and permits the piston to rise, being forced upward by the coil spring within the piston. When the leaf spring expands or rebounds, the piston is depressed and forces oil out of the needle-valve port placed between the cylinder and the oil-supply chamber. Obviously, the force of the rebound is largely expended in forcing oil through this port, so that the rebound is controlled to a point where it is no longer objectionable. On the upstroke following the downstroke, oil flows back into the cylinder past the ball valve.

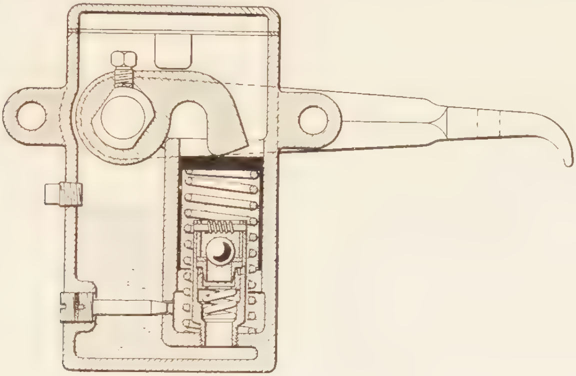


Figure 159.—Interior mechanism of Hydro-Check hydraulic shock absorber

If unusual circumstances cause the development of excessive pressure, it is relieved by the opening (downward) of the sleeve valve against the small coil spring; this permits oil to flow from the cylinder to the supply chamber by way of the port opposite the seventh right coil, counting from the top. The shock absorber allows free action of the springs on small bumps because of the air chamber under the head of the piston. Thus, slight downward motion of the piston results in negligible compression of the air without any appreciable action on the oil. A filler plug in the side of the instrument determines the oil level. The oil level is sufficiently below the rocker-arm shaft so that no leakage occurs at this point. The shock absorber is adjusted by removing the lock screw and then turning the needle valve in or out as required.

GABRIEL TRIPLE-HYDRAULIC SHOCK ABSORBER

2522. The Gabriel triple-hydraulic shock absorber is a two-way instrument—that is, it controls both spring recoil and spring compression (Figure 160). It takes its name from the fact that the drop-forged paddle attached to the shock absorber shaft has three vanes (Figure 161), and it is principally due to this unique, patented feature that the company regards its new instrument as especially effective on all cars, on all roads, at all speeds, with a simple adjustment to meet the individual requirements of all owners.

2523. On looking at the photograph of the triple-vane it is seen that when it rotates anti-clockwise it controls spring recoil, and when it moves clockwise it absorbs the shocks of spring compression.

2524. The clearances at the ends and sides of the triple-vane are four or five times greater than ordinarily used on shock absorbers of this character, therefore, if the vane is moved slowly as on mild boulevard bumps, the oil can pass freely around the sides and ends of the vanes. The resistance thus offered by the shock absorber is so slight that the highly de-

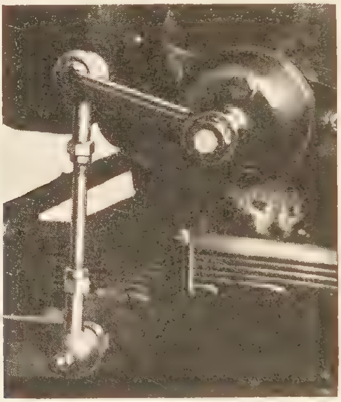


Figure 160.—View of left-front Gabriel triple hydraulic shock absorber on Hupmobile car

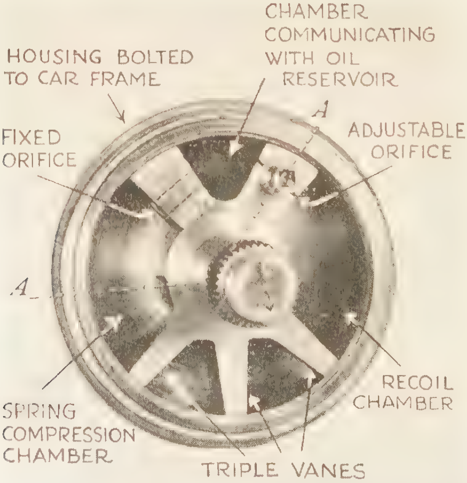

CHAMBER
COMMUNICATING
WITH OIL
RESERVOIR
HOUSING BOLTED
TO CAR FRAME
A
FIXED
ORIFICE
ADJUSTABLE
ORIFICE
A
RECOIL
CHAMBER
SPRING
COMPRESSION
CHAMBER
TRIPLE VANES

Figure 161.—Interior of shock absorber chamber, showing fixed segment and the three "paddles" or blades of the movable vane shaft

sirable, free action of the springs is unaffected, permitting them to absorb fully the small bumps encountered on a smooth road.

2525. On the other hand, if the triple-vane is moved quickly, as it would be on more severe bumps, the oil within the pockets attempts to get out, and in so doing immediately seals up the ends and sides of the triple-vane, the resistance being built up in proportion to the severity of the blow. Thus, the harder the blow the greater the resistance supplied to control it.

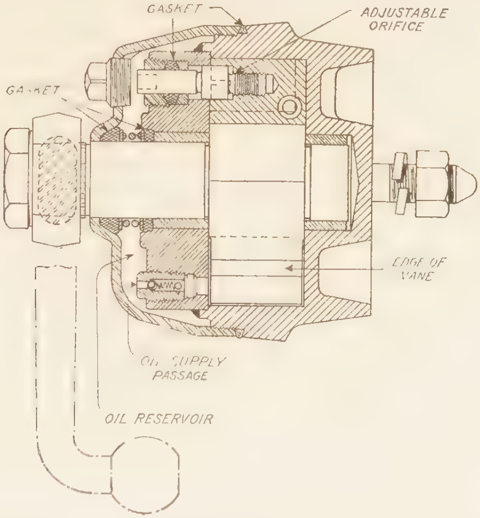


Figure 162.—Section through Gabriel hydraulic shock absorber

2526. When sealing action occurs, due to rapid movement of the triple-vane, oil is forced through an orifice into the small upper chamber which communicates with the oil reservoir shown in the sectional view, from whence oil flows back into the vane chamber past the check valve (Figures 161 and 162).

2527. A fixed orifice is used for controlling the discharge of liquid during spring compression, whereas an adjustable orifice is employed for spring recoil so that the degree of recoil control may be regulated as desired. As shown in both the photograph and the drawing, this orifice consists of a slit, with the effective area of the slit controlled by adjusting the screw.

2528. Due to the liberal clearance around the triple-vane, it is pointed out that the device is unaffected by changes in temperature; also, because of these clearances a smooth, floating ride instead of a stiff, rigid ride results on smooth roads; whereas on more severe bumps the action of the device is less abrupt than it otherwise would be.

2529. Excessive wear and rattling have been eliminated in the shock absorber linkage by forging ball joints on the shock absorber arm and axle bracket. These joints are surrounded by graphite-bronze sockets which require no lubrication; these in turn are mounted in specially-treated rubber sockets which are carried in the ends of the stamped steel link that connects the two ball joints.

SUMMARY

2530. It is impossible to give general directions for the care or adjustment of shock absorbers because they vary so greatly, and all that it is practicable to say on this point is that some shock absorbers require occasional lubrication and some do not; some require occasional adjustment and some do not. In any case, shock-absorber service should be done by a man who is thoroughly familiar with the particular device on a given car.

SPRING RATTLE

2531. If a disagreeable rattle is produced by loose spring shackles, the spring bolts should be adjusted, if possible. Inasmuch as methods of adjustment vary greatly it is advisable to have your repairman do this work, although if you wish to do it yourself, experiment will usually indicate that one nut on the spring bolt is an adjusting nut, which is locked by a cotter-pin (Figure 163, A), or by another nut, usually on the opposite end. After the locking device has been loosened, the adjustment should be drawn up as tightly as possible without using force and then back off one-sixth revolution. If the spring shackles are drawn up so tightly that spring movement is prevented spring breakage will occur sooner or later, and immediately if the shackles are very tight. Figure 163, B shows spring-bolt construction that adjusts itself automatically because of the coil springs shown.

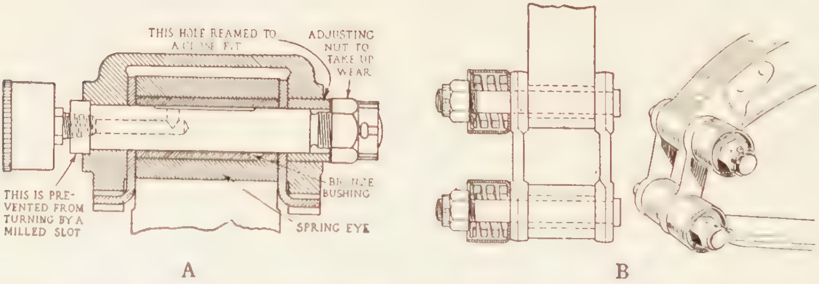

THIS HOLE REAMED TO A CLOSE FIT
ADJUSTING NUT TO TAKE UP WEAR
THIS IS PREVENTED FROM TURNING BY A MILLED SLOT
BRONZE BUSHING
SPRING EYE
A
B

Figure 163. *A*, Spring bolt construction showing method of adjustment; *B*, spring bolts which adjust themselves

2532. To eliminate shimmy, tramp, and other front-end troubles, also to render negligible the road shocks transmitted to the steering wheel, the Packard now is fitted with a movable rear shackle on the right-front spring in addition to the customary shackles used at the front ends of these springs. (Hupmobile is also using a device similar in principle but different in detail on its eight car.) The rear end of the left front spring (Figure 164), instead of being pinned immovably to the frame, is also shackled so that the spring may play back and forth at this point as well as at the front, but the play of the rear shackle is constrained by mounting two stiff coil springs at either side of the triangular-shaped shackle. Ordinarily, these stiff springs hold the rear shackle stationary or nearly so, the main play being in the front shackle; but if the forces acting on the axle are great enough, the rear shackle will yield.

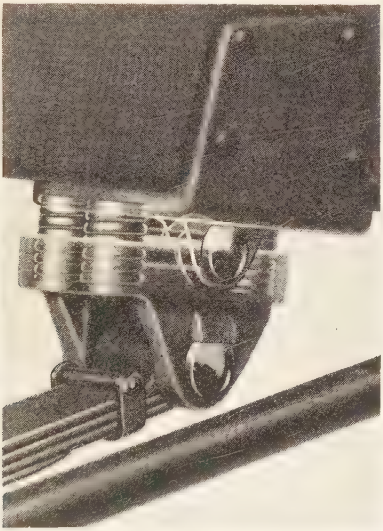


Figure 164.—Spring-controlled shackle at rear end of left-front spring

2533. Thus, when a severe bump is struck by the left-front wheel the force of the jolt, instead of being carried up to the steering wheel, is spent in forcing the axle back slightly on the left side due to the yielding of the special shackle. If the right-front wheel hits an obstruction or if both wheels do, the shock is absorbed with equal effectiveness, although the action of the device may not be clear without explaining that when the right wheel receives a shock, the shock has two places to go: (1) up to the steering wheel; or (2) into the special shackle, whose springs are so proportioned that it absorbs so much of the jolt that any remainder which goes up to the steering wheel is not enough to be noticed.

CAUSE OF SHIMMY

2534. The action of the device in controlling shimmy is somewhat similar. In studying this problem in past years, Packard engineers proved to their satisfaction that a primary cause of shimmy was the flapping of the front wheels caused by the drag-link as the axle moved up and down, and as proof of this view they found that by eliminating the drag-link by the use of an experimental hydraulic steering gear, shimmy was entirely cured even with unbalanced wheels, soft tires, and so forth.

2535. The hydraulic steering gear was never considered as a production possibility, but it did show that the shimmy trouble was essentially in the drag-link. As already mentioned, shackling the springs at the front reduced shimmy tendency, but it did not entirely remove it because even with the rear ball of the drag-link approximately in line with the axis of the rear spring bolt on the front spring, and the front ball in line with the center of the axle, it is clear that as the curved front spring is compressed and becomes flatter the axle moves forward. In other words, the forward movement of the axle is about half as much as the forward movement of the front spring shackle. Similarly, when the spring is expanded on the rebound, the curve of the spring increases and the axle moves backward about half as much as the front shackle. Meanwhile, the front ball joint is moving on an arc of constant radius, therefore this backward and forward axle movement must flap the wheels from side to side. The flapping is so slight that it is impossible for the eye to see it, nevertheless it is there. The rotating wheels, of course, have a gyroscopic action, and while the nature of a gyroscope is far too technical a matter to be discussed here, at least it may be said that because of gyroscopic action, the wheels try to resist the flapping tendency; but if forced to flap, gyroscopic action alternately lifts and depresses each wheel as it flaps from one side to the other and thus at certain road speeds the forces acting on the wheels synchronize so that shimmy occurs.

2536. Flapping is prevented on Packards because the action of the drag-link, instead of causing flapping, moves the axle back and forth slightly against the resistance of the rear shackle on the left front spring. Therefore, as flapping can not occur, shimmy can not occur.

SPRING REMOVAL

2537. To remove a spring, jack the car up so that all weight is removed from the spring, securely blocking it in this position, if blocks are available. Remove the spring bolts at front and rear of spring, remove spring clips and lift spring out. To replace spring, put in spring bolts first and then attach spring clips. Remove jack and give spring clips a final tightening. If the rear spring shackles are reversed through error, remove and replace correctly, otherwise the shackle may lock the spring after going over a severe bump, and if the fact is not discovered, spring breakage may result. If the shackle locks, bend it back to normal position; if this is impossible, drive carefully until the shackle can be corrected.

SPRING LUBRICATION

2538. Rusting and squeaking of spring leaves may be prevented by lubricating them every few thousand miles, although it should be noted that a few car manufacturers object to spring lubrication, and spring lubrication is not always advisable if the springs are already too flexible for comfort. Lubrication not only prevents rust but it increases the flexibility by cutting down the friction between the leaves; therefore, the riding qualities of springs that are too stiff is improved by lubrication. Many methods of lubrication are available. Anti-squeak liquids may be purchased which may be squirted on the edges of the leaves. Another easy method is to smear the edges of

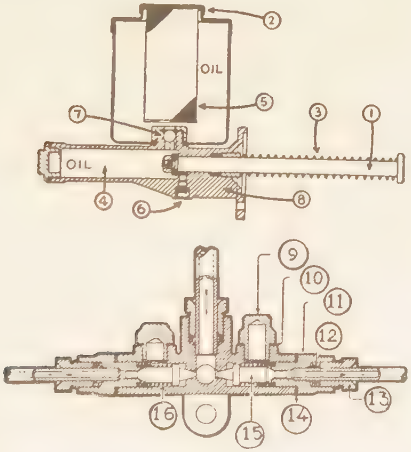


Figure 165.—"One shot" oil reservoir and plunger:

1—Plunger
2—Reservoir filler cap
3—Coil spring which returns plunger to normal position after depression
4—Reservoir oil chamber—compression equal to displacement of plunger
5—Removable filter screen which collects dirt and grit from oil before oil enters distributing passages
6—Outlet through which oil flows to distributing tubes
7—Ball check valve, opens on return stroke
8—Packing flange
9—Air chamber in which oil collects under air pressure. Various size chambers proportion the quantity of oil
10—Oil chamber gasket
11—End connection
12—Pipe sleeve for special alloy pipes
13—Pipe nut
14—End connection gasket
15—Double end valve—cannot stick
16—Valve spring—each valve operates independently

the leaves with a half-and-half mixture of kerosene and cylinder oil, allowing the lubricant to work in while the car is used for a day or so and then wiping the edges of the spring leaves clean. A more effective method is to remove the rebound clips (Figure 156), and spread each leaf with a cold chisel or a spreader which may be purchased for the purpose. Almost any lubricant will prove satisfactory, cylinder oil, transmission oil, or grease; but the lubricant generally recommended for this purpose is a graphite grease, which may be spread on the surfaces of the leaves with a putty knife or similar tool. Be sure to replace the rebound clips after the job is done.

2539. To eliminate the nuisance of spring-bolt lubrication, as well as stopping spring-bolt rattles, the practice of eliminating spring bolts in favor of other types of construction has been growing to a certain extent. Some cars, for example, have the spring ends mounted in suitable rubber blocks called rubber shock insulators, and other cars have the ends of the springs supported by rubberized fabric straps.

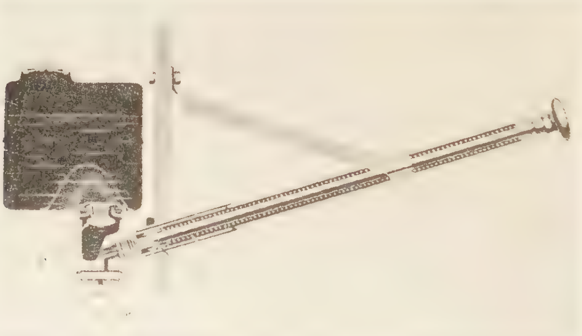


Figure 166.—Packard system of chassis lubrication

2540. Still another method of eliminating the time required for chassis lubrication is to fit the car with a suitable reservoir pump and small pipes leading to the various points on the chassis requiring lubrication, in which case the chassis may be lubricated simply by depressing the plunger which is in the driver's compartment.

2541. On some cars the "One Shot" centralized chassis lubricating system is used (Figure 165). The upper portion of the figure illustrates the oil reservoir and pump plunger, the unit being placed forward of the dash with the plunger extending through into the driver's compartment. The valve mechanism shown in the lower illustration measures a definite quantity of oil to each point on the chassis to be lubricated. The system should be flushed with kerosene every 5,000 miles. The plunger should be depressed once every few hundred miles, oftener if squeaks occur.

2542. The Packard system of chassis lubrication includes a reservoir forward of the dash and a plunger sticking through the dash, the handle of which is pulled out all the way when lubrication is required and then allowed to return gradually by its own spring pressure (Figure 166). This action delivers the oil by individual pipes to various points on the chassis. The pump should be operated once a day. The reservoir should be filled with a good grade of medium oil. The capacity of the reservoir is one quart, which is sufficient for about 75 strokes of the plunger.

2543. The manufacturer's recommendation should be followed concerning spring lubrication. In other words, if the spring has been designed to be used without lubrication, lubrication is likely to make it too flexible; on the other hand, if the spring is designed for lubrication, lack of it is likely to make it too stiff.

2544. Spring covers are desirable in that they keep the lubricant in and the dirt out. Most covers are provided with an oil hole or a grease connection so that lubricant may be automatically supplied from time to time without going to the trouble of removing the covers and separating the leaves.

Chapter XXIII

TIRES

2601. Experience has amply proved that good tires and tubes are cheapest in the long run. Low-priced tires, whether seconds, rebuilt, or cheap new tires, rarely give the low cost per mile that good new tires give. And good tubes are just as essential as good tires. Poor tubes are likely to become porous prematurely.

2602. In purchasing a tire, in addition to knowing the correct size, it is also important to know whether the tire is to go on a straight side or clincher rim (Figure 167), although at the present time clincher tires are made almost exclusively in the 30x3, 30x3½, and 31x4 sizes, although the two latter are also made with straight sides. All other tire sizes are straight side, except for some foreign cars which still use clincher tires.

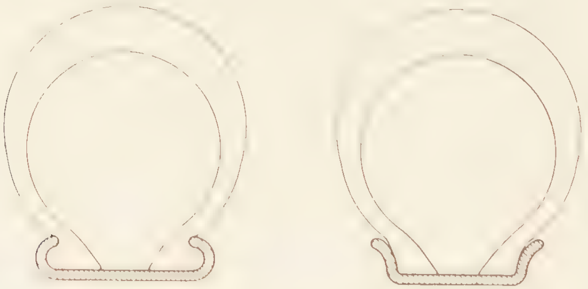


Figure 167.—Straight-side and clincher tires

TYPES OF TIRES

2603. Most tires are cord tires, as distinguished from fabric tires. The difference between these two types is entirely in the construction of the cotton "fabric" built into the tire to withstand the air pressure. In the fabric tire several layers of woven fabric, similar to canvas, are used, whereas in the cord tire the layers consist of cords laid parallel. Longer life and greater flexibility are the chief features of the cord tire. Its general adoption has resulted in the almost complete elimination of tire trouble, as it is unusual for a cord tire to require repair.

2604. In principle of construction, balloon tires are no different from ordinary tires. They are larger, require a lower inflation pressure, therefore fewer layers of cords are necessary. For a given car, the larger the tire, the lower the inflation pressure required, and the lower the pressure the better the car rides on rough roads.

2605. Tires of the same rim size are interchangeable, consequently it is possible to change to a larger size where a larger size is desirable, as shown by the following table:

TIRE AND RIM SIZES

Rim diameters, inches 18	 19	 20	 21	 23
		Tire sizes		
		28 x 4.40		
			29 x 4.40	
			30 x 4.50	
	28 x 4.75	29 x 4.75		
		29 x 4.95		
	29 x 5.00	30 x 5.00		
28 x 5.25	29 x 5.25			
		30 x 5.25	31 x 5.25	
	29 x 5.50	30 x 5.50		
		30 x 5.77		33 x 5.77
30 x 6.00	31 x 6.00	32 x 6.00		
			33 x 6.00	
30 x 6.20	31 x 6.20	32 x 6.20	33 x 6.20	
30 x 6.75	31 x 6.75	32 x 6.75		
			33 x 6.75	32 x 6.75

2606. Recently, it has been agreed to mark the tire cross-section and rim diameter on the tire instead of the tire cross-section and tire diameter. For example; a tire previously designated as 28 x 5.25 may now be designated as 5.25 x 18.

2607. It is usual to carry one or more spare tires already inflated, therefore when a tire must be changed it is merely necessary to unbolt the tire and its rim from the wheel and put the spare one in its place, although if wire or disc wheels are used it is common practice to remove the whole wheel.

TIRE REMOVAL

2608. If the tire is on a demountable rim it should be removed as follows: Jack wheel up at least ½ inch off ground and remove nuts holding the rim wedges. Remove dust cap and nut surrounding tire valve. Rotate wheel until tire valve is at top, pull tire clear of rim at bottom, and then lift off (Figure 168).

2609. To replace tire and rim, reverse the foregoing procedure. If there is a nub or boss on the inside of the rim near the tire valve, be sure that it is put on in such a way that it fits into a hole in the felloe of the wheel. If the wedges bear against a locking ring do not forget to replace the ring and be careful that the ends of the ring are covered by a wedge. Replace the wedges and turn the nuts up finger-tight. Then draw the nuts up as much as possible with the rim wrench without using any force. Then go over nuts again, tightening them as much as possible. Replace the nut on valve and tighten it securely.

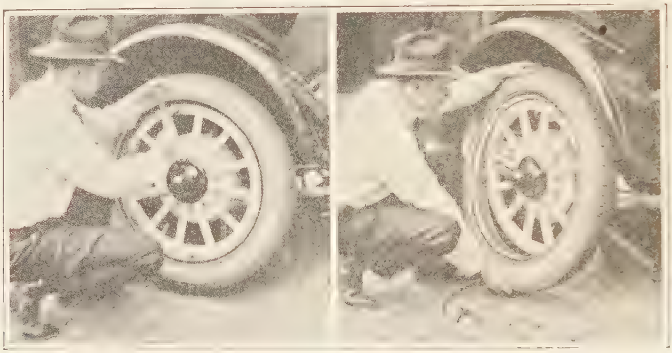


Figure 168.—Removing tire and rim from wheel

2610. To remove a disc wheel, jack wheel up, and remove the nuts holding the wheel to the hub. In replacing, reverse this process. If there is a tubular pilot bar in the tool equipment, the replacement of the wheel is facilitated by placing this bar on the lowest screw stud on the wheel and then using the bar as a guide while the wheel is slipped on. As soon as the wheel is in place, screw a couple of nuts on with the fingers and then remove the pilot bar.

2611. To remove a wire wheel, jack it up and unscrew hub cap with a special hub wrench. The hub caps on the right side of the car should be turned in a counter clockwise direction and on the left side of the car in a clockwise direction, for removal. (The left side of car has right-hand thread and right side a left-hand thread.) Be sure to get wheel on all the way, before replacing the hub cap.

2612. Demountable rims or wheels are not used on some of the smaller cars, in which case the tire must be removed at the wheel. (See paragraph 2625.)

2613. Before jacking up a car for any reason, see that it is on fairly level ground. Put on hand brake before jacking up a front wheel, and block one front wheel with a large stone, before jacking up a rear wheel, then

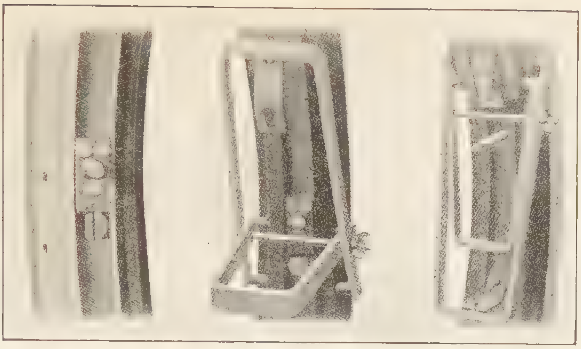


Figure 169.—Tool for collapsing demountable rim

release the hand brake and be sure that the gear is in neutral; otherwise the wheel can not be turned as required.

2614. To remove a tire from demountable rim, first fully deflate it by pressing down on small wire plunger slightly protruding from valve opening, although a quicker method is to remove the valve by screwing it out counterclockwise, using the valve cap turned upside down as a wrench. The method of procedure from this point varies somewhat, although all modern American automobiles are provided with split rims—that is, the rim is cut crosswise at one point. Sometimes, a locking screw must be turned (Figure 169), and then the rim may be contracted by means of the rim tool shown. There are other types of rim-contracting tools, but in any case a careful examination of tool and rim should reveal the method of operation.

2615. As a rule the tire may then be lifted free from the rim without difficulty, although if it is rusted in place it may be necessary to pry it free with a large screwdriver or similar tool; be careful, however, not to injure the tube in the process.

2616. If a rim tool is not available, completely loosen tire from rim by prying it away with a screwdriver; this is merely to free the tire where it has rusted. Then pry rim apart with a screwdriver as shown in Figure 170, *A*,

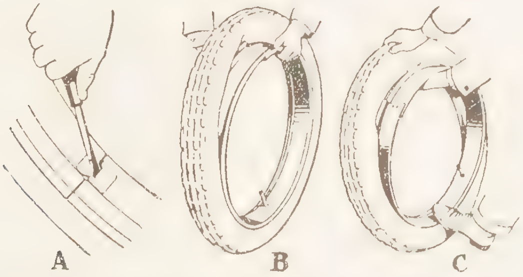


Figure 170.—Collapsing the rim and removing a tire without using rim tool

allowing one end of rim to telescope over the other. Then remove tire from telescoped portion as shown at *B*, using a large screwdriver or similar tool, if necessary, to pry tire loose. Lift rim off as shown at *C*.

2617. Remove flap from tire and then remove tube. If a tube is badly stuck to tire, pull it away little by little, otherwise it may be torn.

MOUNTING TIRE

2618. To replace a tire in a tube inflate it slightly—just enough to make tube approximately round when lying flat on the ground. First be sure that the valve has been replaced and screwed down tight. Too much inflation, however, will prevent mounting of tire on rim. Remove all dirt from shoe and be careful not to get tube dirty while handling it. Rub the surface of the tube with tire talc, and dust some into the shoe, but do not use too much. New tubes usually have sufficient talc on them.

2619. Tuck the tube into the shoe, being careful not to twist the tube. After the tube is in place run the fingers around between tire and tube to be sure that it is lying flat at all points. Then put the flap in place, taking care that it lies flat between tube and shoe.

2620. To replace tire on rim, slip valve through opening in rim, and then work the remainder of the tire down over the rim carefully. This is usually an easy job if the rim is contracted with a rim tool, but a little more difficult otherwise. In either case a large screwdriver or similar tool is of assistance as a "shoe horn." Pry the far side of the tire on to the rim first, and then pry the near side on, being careful not to disturb the flap or to cut or pinch the tube with the screwdriver. With tight tires it is necessary to work the tire on gradually, proceeding alternately in both directions from the tire valve. If the tire goes on readily it may often be forced in place with the feet (Figure 171). Be careful that the valve stem is kept straight.

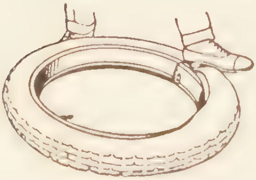


Figure 171.—Forcing tire on rim

2621. After the tire is in place expand the rim with the rim tool, or otherwise pry the rim shut with a screwdriver. Sometimes it may be necessary to strike the joint a few sharp blows with a hammer to bring the two ends of the rim flush. Secure the joint with the locking device, if there is one.

2622. Bounce the tire a few times and then inflate it. If a tire gage is not available, replace the tire on the wheel before fully completing inflation, and remove the jack. Then inflate the tire until it stands up as round as desired.

REMOVING TIRE FROM DEMOUNTABLE WHEEL

2623. To remove a tire from a demountable or wire wheel, fully deflate the tire, by depressing the valve or removing it. Then pry the locking ring loose if it is not secured by nuts. If it is secured by nuts, remove them and then remove the locking ring. Remove nut at valve stem and then pull tire off. If the tire is badly rusted it may be necessary to pry it loose with a large screwdriver or tire tool.

2624. To replace, reverse the process, handling the tire and tube as described in paragraph 2618.

REMOVING CLINCHER TIRE

2625. To remove a clincher tire, jack up the wheel, remove the nut surrounding the valve stem, completely deflate tire and push valve stem as far as possible into tire. Pry near side of tire loose from rim using a screwdriver or tire tool. It is generally advisable to have two tools, holding the portion of the tire already pried off, while working with the other tool. After the near side is completely off of the rim, remove the tube. Then pry off the far side of the tire in similar fashion. If only the tube is defective it is not necessary to remove the far side of the tire.

2626. To replace, reverse process. The tube should be slightly inflated before being replaced. Before replacing tire, it is advisable to scrape all coarse rust particles from the rim, as the tube rests directly on the rim and is likely to be cut by them (as clincher tires do not have flaps). In replacing a tire be careful not to pinch the tube between the tire and the rim, nor cut the tube with the tire irons.

TIRE CARE

2627. To obtain maximum tire economy, the tires should be kept properly inflated, according to the pressure advised by the tire manufacturer or your tire dealer. If this information is lacking, inflate your tires to 35 to 45 pounds, the larger figure being for the heavier cars. Test inflation pressures frequently with a gage.

2628. Avoid sharp obstructions, not only glass, but car switches, and sharp stones, large or small. The two latter are particularly likely to cut the tread or puncture the tire when wet. Excessive use of car tracks will also shorten tire life. It is best to run slowly over roads filled with sharp stones, coasting when possible and applying the brakes only when absolutely necessary and then as gently as possible.

2629. Avoid locking the wheels and skidding around corners. Both rub the tread rapidly from the tires and impose severe strains on the carcass as well.

2630. Do not allow the side walls to scrape against the edge of a curb, and drive as little as possible in dried mud or ice ruts. These things quickly tear and scrape the rubber off of the side walls, thus greatly shortening the tire life.

2631. In turning around in a street do not allow the tires to strike against the curb. Even a slight blow may cause a blow-out later, and a severe blow, incidentally, may bend the axle or break a steering knuckle, or wheel spindle.

2632. Tread cuts and sand blisters should be repaired as described in paragraph 2662 and paragraph 2665 respectively, to prevent rapid tire deterioration.

2633. Do not allow tires to stand in gasoline, oil, or water.

2634. Keep front wheels in alinement. (See paragraph 2310.)

2635. Avoid sudden stops and starts.

2636. Whenever a tire is removed from the rim, it should be examined as described in paragraph 2645.

2637. Tire treads should be examined frequently for nails and tread cuts. Frequently, if nails are pulled out soon after they stick into the tire, punctures will be avoided. If tread cuts are filled soon after they occur, rotting of the tire structure will be prevented, (see paragraph 2662).

2638. It is never advisable to operate the car without a good spare tire, otherwise if a blow-out occurs it may be necessary to run several miles on a

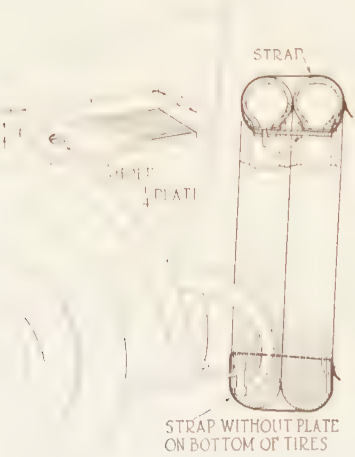


Figure 172.—Simple method of carrying second spare tire

flat tire, with the result that the tire will be ruined. Do not assume that a spare is not required with new tires, because a new tire is liable to puncture. If the tires on the car are in poor condition, two spare tires and tubes should be carried, or if the tires are in good condition, but the spare is nearly worn out, it is advisable to have two spares. In any case, in addition, it is desirable to carry a spare tube and a blow-out patch.

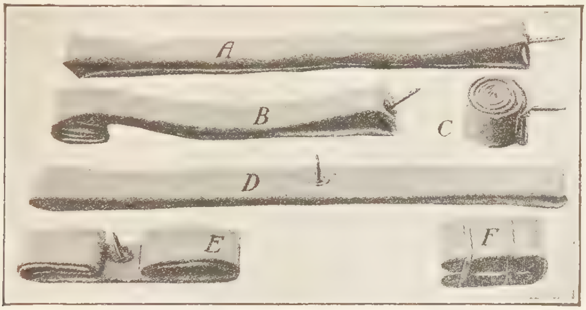


Figure 173.—Correct method of storing spare tube

2639. Simple, inexpensive fittings may be obtained so that two spare tires may be carried on a tire carrier built for one, although many drivers prefer to strap the second spare to the first, and here it should be noted that exceptionally strong fabric straps may be obtained for the purpose. At least three straps should be used, and to prevent the sagging of the second spare it is advisable to install a bracket as shown in Figure 172. It is simply a piece of metal, about 2 by 5 inches by $\frac{1}{4}$ inch, with a $\frac{5}{8}$-inch hole bored near one end so that the tire valve can slip through it. It is placed between the rim of the first spare and the tire carrier as shown.

2640. It is advisable to have a tube repair kit in the car, a half-dozen extra valves, and a tire gage. The spare tube should be folded as shown in Figure 173, all air having first been exhausted by removing the valve and rolling the tube up. A spare tube should be protected by carrying it in a cloth bag, or doing it up in heavy paper. A loose tube is likely to be punctured by chafing.

BLOW-OUTS

2641. Symptom—Blow-outs.

2642. Cause and Cure Ordinarily, when a modern tire blows out it means that it is worn out and should be discarded. This is certainly true if the tread is nearly worn out. Those who wish to avoid unexpected blow-outs should discard a tire as soon as the tread wears off sufficiently to expose the breaker strip, for even though the tire may not blow out for some time there is a good possibility that it will be punctured, especially by a sharp stone.

2643. If the tire is new, its manufacture was defective or it has been abused. In the former case, see the man from whom you purchased it.

2644. If the tire has seen considerable service but the tread is not worn out, it is necessary to decide whether the remaining life in the tire is worth the cost of repairing, and to determine this it is necessary to obtain an estimate as to the cost of repairing the tire, and balance this against the probable tire life; retreading rarely pays.

2645. Even if the tread is in good condition, a tire is usually not worth repairing if much of the tread is rotted or loose, if it is rim cut, or if the interior of the tire has any cracks, either incipient or well developed. The beginning of a crack is indicated by a line of cotton fuzz due to the breaking of the strands in the cords. The tire must be spread open and scrutinized minutely at all points of the interior. Both cracks and incipient cracks (checks) may not be noticed unless the inspection is exceptionally thorough.

2646. If the tire is worn out it is advisable to run slowly on it for about 300 feet to loosen it in case it has rusted to the rim. Before doing so be sure that the nut surrounding the valve stem is tight, otherwise the tube will tear. However, do not do this if the tire is not worn out.

2647. If you have a spare tire, put it on, but if not, use a blow-out patch; be careful to install it so that it does not pinch the tube. A blow-out patch covered with Holland cloth may be cemented to the shoe. The method being the same as for patching tubes, paragraph 2660.

2648. If you have neither, and the tire is worn out, run slowly on the flat tire. A high speed on a flat tire, especially on a rough road, is not only likely to damage the rim, but perhaps harm the axle as well. If the tire is in good condition, except for the blow-out, it is advisable to remove it to prevent further damage, proceeding on the bare wheel. Under these circumstances slow speed is especially desirable.

2649. A rim damaged by running flat should be straightened before mounting a new tire on it; otherwise the rim may cut the tire, or the tire may blow off, depending on the character of the injury.

TIRE FLAT

2650. Symptom—Tire flat, often termed a "flat."

2651. Note: When running, the first indication of a slow puncture may be "wandering" of car at high speed on a straight road or skidding of rear end at moderate speeds on sharp turns. The first symptom of a soft front tire may be a tendency for car to pull to one side of the road, coupled with hard steering at low speed. Finally when the tire is sufficiently deflated it thumps on the road.

2652. Causes (1) Leaky valve. (2) Puncture. (3) Pinched tube. (4) Small blow-out. (5) Other tube defects.

2653. Cure 1. When a tire becomes flat and it is not blown out, look first for a leaky valve, the common method of testing being to cover the valve opening with saliva, and noting if a bubble is formed. If the valve leaks, allow some air to escape by pressing in on the valve stem, thus blowing any dust off of the valve seat. If necessary, inflate the tire to make this test. If the valve still leaks, remove it and put in another, screwing it out by using the top of the valve cap as a wrench. It is advisable to carry spare valves, but if none are available, remove the valve from a spare tube, or spare tire.

2654. Cure -2. If the valve is all right, examine the tire carefully for a nail, tack, piece of glass, sharp stone, or the like. If it is inconvenient to change the tire, and the puncture is due to a nail, the tire may often be run for many miles, if it is re-inflated. This, of course, only holds true when the leak is a slow one. However, it is generally advisable to change the tire immediately. Later, when you have a convenient opportunity, remove the tire from the rim and remove the tube from the tire. Find and remove the cause of the puncture. If it is not observable from the outside, examine the inside carefully, if necessary, rubbing the fingers completely over the interior, but caution is necessary if finger scratches and cuts are to be avoided. The cause of the puncture must be found before a new tube can be put in. Regardless of the reason for removing the tire it is advisable to examine it carefully as described in paragraph 2645.

2655. Cure—3. If no puncturing agent is in evidence it is probable that the tube has been "pinched." If the tube is literally pinched at any point leakage will occur sooner or later. Pinching may be due to absence of a flap (in straight-side tires), to carelessness in putting tube in tire with the result that a wrinkle is formed in the tube, or to carelessness in inserting the flap so that the tube is pinched between it and the tire; to a cut or wrinkle in the flap a flap with cuts in it should be discarded; to a crack in the tire. The interior of the tire should be carefully examined for cracks. If only one crack is present the tire may be worth repairing, but if there is more than one it is probable that the tire should be discarded. The tire should also be discarded if several checks are found (see paragraph 2645). If the tire is considered to be worth mending, have the crack repaired by a tire repairman, or put in a blow-out patch, or in an emergency when it is necessary to patch up the shoe and tube for a few miles running, put a tube patch over the crack.

2656. Small blow-outs have been included under this head merely because they are sometimes confused with punctures. Treat the blow-out as described in paragraph 2642.

2657. Cure—5. If no punctures or cuts are found in the tube, it may leak around the valve, or a previous patch may have come loose, or the tube may be porous.

2658. Whether the leakage is due to Causes 1, 2, 3, 4, or 5, it is generally advisable to test the tube in water, both before and after repairing. For this purpose the tube should be slightly inflated and then held under water, bubbles indicating leaks. Examine the whole tube because there may be more than one leak. After repairing the tube, test the repairs similarly, but wipe all water from the tube before putting it into a tire.

2659. The cost of repairing tubes is so slight that most drivers find it desirable to have this work done by garagemen or tire repairmen, although it is feasible for the motorist to repair small holes himself. There are various methods of repairing tubes on the road, and the definite instructions issued by the manufacturer should be followed where possible, but if these are not available, the following may be used:

TUBE REPAIR

2660. The puncture found, clean the surrounding surface thoroughly with a rag moistened with gasoline drained from the carburetor. Cut a patch of such a size and shape that it overlaps the injury by approximately 1 inch. This means that a nail hole should have a patch 2 inches in diameter, while a cut 3 inches long should have a patch 2 inches wide and 5 inches long. Roughen the surface of the tube to be patched with sandpaper, or the equivalent—the top of the patch may be used if rough, resembling a cheese grater. Apply a coat of cement and after it becomes dry enough to be tacky (sticky), apply another coat. When tacky, apply the patch, pressing on it 2 or 3 minutes. Before putting the patch in place, remove the thin protecting cloth covering the sticky side, and apply this side to the tube. The union between patch and tube is facilitated by holding the tube against the hot radiator. Dust the patched surface of the tube thoroughly with talc before putting it in the tire to prevent sticking.

2661. The method employed in vulcanizing a tube is similar, except that the tube is clamped in the vulcanizer. In tire-repair shops steam is mainly used for heating the vulcanizer, but portable vulcanizers for the road are heated by one of two methods. A cartridge or disc of specially prepared fuel is put in the vulcanizer and ignited with a match, or the vulcanizer chamber is filled with gasoline. In either case the amount of heat generated is sufficient for the vulcanization of one patch. Electrically heated vulcanizers are also made for the private garage.

TREAD CUT

2662. Symptom—Tread cut.

2663. Cause—Sharp stones and the like.

2664. Cure—Tread cuts allow water and dirt to rot and wear the tire structure, therefore they should be repaired if full tire life is to be obtained. If the cut is a large one it may be advisable to have a tire man repair it, but if small, the following method may be used, provided that the cut is new; if old, see your tire man: Wrap a rag around a small stick, dip it in gasoline and clean the cut until all dirt is removed, and then give it a final scrubbing. Then apply a special self-curing cement made for the purpose, to the surface of the cut and the tire for ½ inch from the hole. Apply a second coat after the first has dried thoroughly. Then take a piece of tire putty about twice the size of the hole, and knead it between the palms of the hands until it comes free and works into a ball. The hands can then be cleaned by rubbing them briskly. Then force the ball into the hole, using a screwdriver or similar tool. The lump of putty should stick up from the surface of the tire as far as the cut is deep, because it shrinks as it dries. Put a piece of clean paper on the floor and allow the weight of the car to rest on the repair overnight. Then trim off any excess rubber with a sharp knife, wetting the blade before use.

SAND BLISTER

2665. Symptom—Sand blister.

2666. Cause—Tread cut.

2667. Cure—Have blister cleaned out and vulcanized by your tire repairman.

VALVE LEAK

2668. Symptom—Valve leak.

2669. Causes—(1) Dirt. (2) Valve worn.

2670. Cure—1. Blow dirt out of valve by depressing valve stem.

2671. Cure—2. Put in new valve, using the valve cap turned upside down as a wrench.

RIMS RUSTY

2672. Symptom—Rims rusty.

2673. Cure Clean with sandpaper or stiff wire brush and apply special graphite paint made for the purpose. Rusting of rims is not serious, if the tube is protected by the flap.

HOW TO APPLY CHAINS

2674. Jack the wheel up and lay the chain on with the ends hanging down. Connect the inner ends together and then the outer ends, being careful that the chain is neither tight enough to bind on the tire nor loose enough to fall off. When traveling in deep mud or snow, it is important to apply the chains so that the slipping of the wheels when going forward tends to close the locking links; in addition, it may be advisable to wrap several turns of iron wire around these links.

2675. Worn or broken cross chains may be readily replaced by prying the old cross chains off and putting new ones in their place. A special tool is made for this purpose, although a hammer and cold chisel may also be used.

2676. Figure 46 shows a typical mud hook for use in extricating a car from deep snow or mud. At least two should be applied to each rear wheel. As a rule it is advisable to back the car out slowly, running the engine at a rather high speed so that it will not stall, and letting the clutch in just enough to exert a slow steady pull. If the mud is soft the movement of the car will be somewhat jerky, but this should not alter the method. Mud hooks will not work if the car digs in so deeply that the rear axle rests on the ground, although do not jump to this conclusion hastily; try the mud hooks thoroughly first.

2677. If mud hooks fail because the mud is too deep, pry the car up on one side with a fence rail or plank, pivoted on a log, the end being placed under the hub of the wheel. When the car is raised slip a plank or large stones under the wheel. Repeat the process on the other side. Back out slowly but surely by running the engine at a good speed and slipping the clutch.

2678. If this fails, have the car towed out by another car, truck, tractor, or horses.

Chapter XXIV

CAR RATTLES AND SQUEAKS

2701. A squeak is an urgent demand for oil, a rattle is a plea for oil that has gone unheeded, and a hum is a fast rattle, the individual beats coming so frequently that a musical sound is produced.

2702. To be sure, some rattles and some hums are produced by legitimate wear, but most of them are wholly or largely caused by neglect of oiling.

2703. The immediate cause of a squeak is a high-pitched vibration between two surfaces in rubbing contact. Naturally, the number of places around a car that are likely to fulfill this condition are unlimited. A squeak may occur almost anywhere and this is what makes it so hard to detect. There is no telling just exactly where it is. But remember, if a squeak can not be found by sense of hearing it may be found by sense of touch; vibration at the point of rubbing contact will reveal it. Sometimes the rubbing is permitted by a loose bolt, in which case the noise may be stopped by tightening the bolt, but more often the noise is caused by a sheer lack of lubricant on a surface that was not designed to run without oil. Other squeaks are due to slight rubbing of surfaces caused by the weaving of the car frame as it proceeds over the road. Numerous hood and body squeaks may be laid to the latter cause. These may sometimes be cured by separating the surfaces with felt or some other suitable material that will prevent rubbing; oil or grease should be used for other squeaks. Consider hood squeaks, for instance. Noises of this character may occur along the hinge, or at the front or rear or bottom edges of the hood. Rubbing at any of these points is caused, not by engine vibration, but by the weaving of the frame. Weaving is another way to describe bending and twisting caused by road inequalities. First one side of the frame will curve up and then the other, and it pushes and pulls the hood with it. Under ordinary circumstances the weaving is hardly noticeable, although the squeaks may be, but the first time the car is driven on a rough road, the extent of frame weaving can be well observed by the way that the hood moves around. The cure is to oil the rubbing surfaces.

2704. Body squeaks are also caused by frame weaving and may be cured by searching out the rubbing surfaces and giving them a liberal dose of oil. And the same applies to an open car top.

2705. Squeaky springs may be cured by applying any one of the many spring lubricants, or by smearing a mixture of oil and graphite on the sides of the springs and leaving it there for a couple of hundred miles or so to give it a chance to work in. Then the sides of the springs may be wiped dry. (See paragraph 2538.)

2706. Rim squeaks are caused by rim bolts that are too loose. Tightening of the bolts will eliminate the sound.

2707. Squeaks in generator, fan, or other parts about the engine or chassis are mostly due to lack of lubricant on the bearings and can be cured by a generous application of oil or grease.

2708. Concerning squeaky brakes see paragraph 2288.

2709. If the speedometer shaft squeaks, detach it at the speedometer and fill it with oil, or if this not feasible, squirt oil into it.

2710. A rattle is produced by the pounding of two loose parts. It may be prevented by eliminating the looseness or by stopping the relative motion between the two parts. The latter method involves the use of a spring of some sort to hold the parts tightly together. Rattles in brake rods, for example, may be stopped by fitting strong coil springs at strategic points.

2711. In many cars the best way to eliminate the rattle is to supply new bushings and pins, and when these are in place rattling may be indefinitely postponed by faithful oiling.

2712. Worn spring bushings and spring bolts are common sources of rattling noises. When a car sounds as though it were falling apart every time that it hits a bump, a good part of the noise may be laid to wear in these parts. New bolts and bushings is the remedy, although this need might have been delayed for a long time with proper lubrication.

2713. Play between the spring eye and the shackle accounts for many rattles when the spring bolts and bushings are tight.

2714. A loose universal is likely to cause a rattle when traveling a rough road with the clutch disengaged or gear in neutral, in other words, when coasting. And when the power is applied a sharp clicking sound will be heard coming from the region of the floor boards.

2715. Rattles may be due to various loose parts; a loose engine arm, a loose headlight lens, a loose bumper mounting, a loose fender, a loose tire carrier, and other parts come in this class. Tools loose in a box or under the seat will produce some decidedly ominous although harmless sounds on a rough road. It is a good plan to wrap the tools up or carry them in a kit bag made for the purpose. One with individual pockets is probably the best; certainly it is much more convenient than carrying them loose.

2716. As a rule, the removal of upholstery to repair upholstery springs, locks, top irons, etc., is a simple matter. Loosen the upholstery layer by layer by removing the tacks holding it, until the desired parts are accessible. After repairs have been made replace the upholstery layer by layer, using new tacks wherever the old ones are bent.

CHAPTER XXV

REPAIRING THE FORD MODEL A CAR

2801. This chapter describes the special points concerning the repair of this car. In this connection it should be noted that all of the previous chapters in this book apply generally to the new Ford, therefore in the following pages only those items which require special attention are discussed:

2802. Numerous changes in its construction have been made since the Model A was originally announced. Therefore, wherever two types of construction have been used the old design is discussed first.

VALVE MECHANISM

2803. The valves used in the Model A engine are accurately ground in at the factory. They form an ideal seat in the cast-iron block, consequently, they should require no further attention for some time.

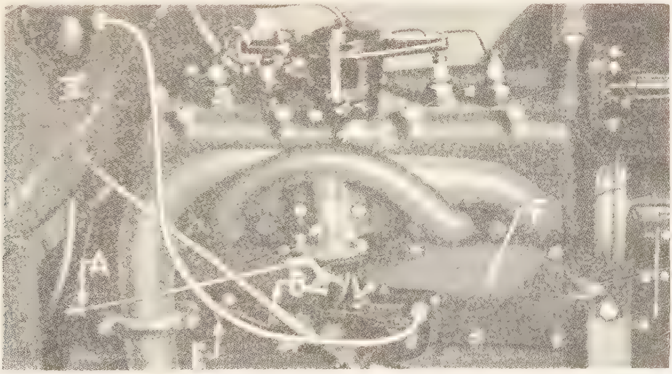


Figure 174.—Ford Model A engine. See text for references

2804. When it does become necessary to grind the valves, proceed as follows: Drain water. Loosen radiator stay rods at radiator. Pull radiator slightly forward and lift off hood.

Unhook spark and throttle rods. (See *A*, Figure 174.) These rods are connected with ball-and-socket joints and are disconnected by holding the rod stationary, and pulling back on the cap.

Disconnect carburetor adjusting rod *B* at carburetor and pull rod back into front compartment. Do not misplace locking sleeve spring and washer which will drop off when adjusting rod is pulled back.

Shut off gas and disconnect fuel line at sediment bulb.

Remove carburetor by screwing out the two carburetor to intake manifold bolts *D*.

Remove fan belt by loosening the generator arm stud nut and generator support to engine bolt and pulling generator towards engine as far as it will go. The fan belt can then be removed from fan.

Disconnect spark-plug connectors and lift off distributor cap and body.

Screw off all cylinder head nuts. Loosen distributor set screw nut *C* and back out set screw until distributor base can be lifted off.

Pull radiator slightly forward and lift off cylinder head complete with water pump and fan assembly. Cylinder head gasket can then be slipped off over ends of studs.

Screw out oil-return pipe bolt upper *E*, and loosen the lower bolt. Push pipe out of way so that valve chamber cover can be removed.

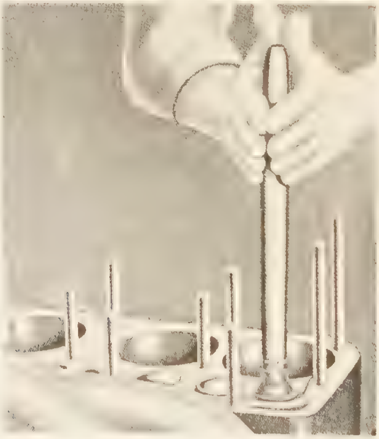


Figure 175—Ford vacuum-cup valve grinder

As a quantity of oil is always standing in the valve compartment it is a good plan to place a drain pan under the rear end of the right hand engine pan before removing valve chamber cover.

Screw out the 10 valve chamber cover bolts and lift off cover *F*.

With a valve lifter compress the valve springs until the valve spring seat retainers can be withdrawn. It is not necessary to remove the valve springs. When compressing the springs the valve lifter is inserted between the lower coils of the spring.

Next, lift up the valves as far as they will go and carefully examine both the valve seats and the beveled face of the valves. If the valves and seats do not require re-facing or re-seating, the valves can be ground in without removing the valve-guide bushings. As the tops of the valves are machined smooth, it is necessary to use a vacuum cup type valve grinder (See Figure 175). The grinder holds the valve by suction. Extreme care must be employed to prevent any carbon or grinding compound from getting into the valve-guide bushings; also make sure that all compound is removed from valves and valve seats when the grinding operation is completed.

2805. Should the valves require re-facing or the valve seats need re-seating, it will be necessary to remove the valve-guide bushings to withdraw the valves. To remove the bushings, lift out the valve springs; the bushings can then be withdrawn through the valve chamber. If the guides bind in the cylinder block they can be removed by tapping them out with a brass rod inserted through the valve opening in the face of the block.

2806. After the re-facing or re-seating operation is completed, replace the valves and insert the valve guides into the cylinder block. The valves should then be lightly ground in to insure a perfect seat. After grinding, always check the clearance between valves and push rods; a thickness gage is used for this purpose. The clearance should be not less than 0.013 inch or more than 0.015 inch.

2807. Carbon must be removed from piston heads with a carbon scraper. Never use a wire brush, as particles of carbon or a strand of wire from the brush are liable to be forced between piston and cylinder wall with possibilities of scoring.

2808. Before replacing cylinder head pour at least a tablespoonful of engine oil around the edge of each piston to insure sufficient lubrication when engine is started. When engine is thoroughly warmed up it will be found that cylinder head nuts can be taken up slightly. Attention to this detail prevents any possibility of gasket blowing out.

2809. To insure a uniform power stroke in each cylinder, it is absolutely necessary that the correct clearance (0.011 to 0.014 inch) be maintained between valves and push rods, and that the clearance be checked with the push rod resting on the heel of the cam (the lowest point of the cam).

When checking this clearance, an easy way to determine that the push rods are on the heel of their respective cams is first to turn the engine over until valves number eight and three are fully opened. At this point, all four pistons will be 2⅛ inches from the top of the cylinder, and numbers 6 and 1 push rods will be resting squarely on the heel of their respective cams and the clearance can be easily checked.

2810. After adjusting the clearance between numbers 6 and 1 valves and push rods, turn the engine over exactly one-half turn. Numbers 7 and 5 valves will now be open, and numbers 4 and 2 push rods will be resting on the heel of their cams.

2811. After adjusting the clearance between numbers 4 and 2 valves and push rods, again turn the engine over exactly one-half turn. Numbers 6 and 1 valves will now be open, and numbers 8 and 3 push rods will be resting on the heel of their respective cams.

2812. After checking the clearance between numbers 8 and 3 valves and push rods, once more turn the engine over one-half turn. Numbers 4 and 2 valves will now be open, and numbers 7 and 5 push rods will be resting on the heel of their cams and their clearance can be checked.

2813. When installing timing gears the word "Ford" on the crankshaft gear should be placed adjacent to the circular depression in the camshaft gear. Back lash should be 0.003 to 0.005 inch.

2814. The timing of the valves is correct if the pistons are on dead center when the timing plug described in paragraph 2848 is in the depression in the camshaft gear.

2815. The camshaft has been re-designed—the new shaft is of the 5-bearing design and replaces the 5-bearing shaft formerly used. The new shaft can be used in both old and new cars. (January, 1929.)

PISTONS AND RINGS

2816. The piston clearance should be loose on a 0.002-inch feeler and tight on a 0.004 inch feeler. Clearance between piston ring and side of groove should be 0.0015 to 0.002 inch; gap clearance, 0.011 to 0.013 inch for top ring; 0.009 to 0.011 inch for middle ring; 0.007 to 0.009 inch for bottom ring. There is a small oil groove near the upper edge of the ring, and care should be used to see that this groove is towards the top.

2817. When fitting a wristpin in piston, select a pin which can not be pressed into the piston by hand at room temperature. Next submerge the piston in boiling water, allowing the piston to remain in the water from one to two minutes, then withdraw piston, wipe out piston pin holes with a clean cloth and insert pin. If properly selected, the pin can then be pushed into the piston with a slight pressure of the hand. Taking the chill out of the pin by holding it in your hand for a few seconds and then applying a light film of oil on the pin will make it easy to install.

2818. The upper end of the connecting rod has 0.040 inch total side play between the wristpin bosses in the piston.

2819. Some Model A cars are now being equipped with solid-skirt pistons (Figure 176). These pistons are a trifle lighter than the slotted-skirt design, consequently, they should not be used interchangeably (January, 1929).

2820. The piston heads in the solid skirt pistons are fitted with a non-expanding steel insert anchored to the center of the piston head. This steel insert projects through the second ring groove and bears against the piston ring, which in turn rides against the cylinder wall. The insert and ring are snugly fitted to the cylinder and hold the piston in a centralized position. The skirt of the piston is machined to an oval cone with its largest diameter across the piston pin and in line with the connecting-rod wall thrust.

2821. With the piston cold, the lower end of the skirt fits snugly across the pin with ample clearance in front and rear. This gives the piston approximately zero clearance in line with the connecting-rod thrust and ample clearance in the cylinder at the front and rear of piston to allow for necessary expansion. Feelers should not be used when fitting these solid-skirt pistons. The pistons should be a snug fit at top and bottom across the cylinder.

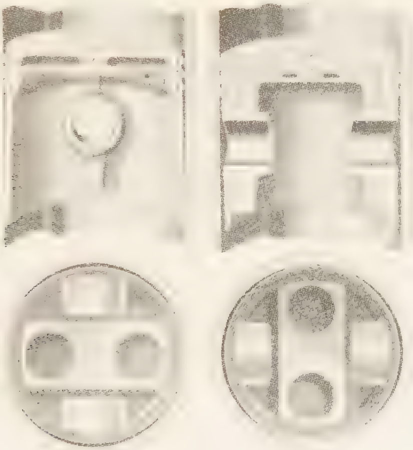


Figure 176.—Solid skirt piston

CONNECTING-RODS, CRANKSHAFT, AND FLYWHEEL

2822. The lower end of the connecting-rod has 0.008 to 0.012 inch total side play and its bearing clearance is 0.0015 inch.

2823. Before assembling the connecting-rods to the pistons, each rod must be accurately alined on the connecting-rod alining jig. Because of the design of the solid-skirt piston, it is unnecessary to check the assembly for alinement after the piston is assembled to the connecting-rod.

2824. Main bearing clearance in inches is: Front, 0.0015; center, 0.002; rear, 0.0025; thrust clearance on rear main bearing, 0.004 to 0.007. Main bearings are line reamed 0.001 larger than the crankshaft journals.

2825. Some Model A engines are now being equipped with cast-iron back rear main bearing caps. (April, 1929). The new cap can be readily distinguished from the forging design by the difference in the thickness of the bolt bosses. The bolt bosses on the cast-iron design are $1\frac{1}{8}$ inches thick, whereas on the forging design the bolt bosses are $\frac{9}{16}$ inch thick.

To compensate for the additional thickness of the bolt bosses on the cast-iron back bearings, main bearing bolts, $4\frac{3}{16}$ inches long are furnished for this type of cap; these bolts are $\frac{9}{16}$ inch longer than the bolts used with the forging design cap.

2826. After installing a flywheel, check both rear face and hub for eccentricity and wabble, with an indicator. If out more than 0.005 inch a new flywheel should be installed.

2827. After installing a flywheel housing, always check the rear and the counterbored faces of the housing to see that they are in alinement with the face of the crankshaft flange. An indicator is used for this purpose. If either the inner or counterbored face of the housing is out of alinement with the crankshaft flange more than 0.006 inch, insert a 0.010 inch shim between cylinder block and both the upper bosses on flywheel housing. If this fails to draw the housing into correct alinement, install a new housing.

2828. The motion of the cotter-pin in the drain hole in the flywheel housing prevents the drain hole becoming clogged.

LUBRICATION

2829. For correct engine lubrication a high-grade, well-refined oil is essential. As a guide to the proper viscosity or body of oil for summer and winter conditions, which vary for different territories, the lubrication charts of reputable oil companies should be consulted. In general, an oil having the body of Society of Automotive Engineers viscosity No. 40 corresponds approximately to our M-515-A and B and is accordingly recommended for summer use. For winter use, S. A. E. oil specifications No. 20 can be used. It is necessary, however, for winter use, that such an oil have a low cold test. A large number of oil companies are stamping containers and indicate on their charts S. A. E. numbers. This practice is desirable because it assists the owner to obtain the proper oil for his engine. When changing the oil in the engine, fresh oil can be poured in more rapidly if the oil level indicator is removed.

2830. The oil pump may be removed after removing screws which hold it to oil pan and after removing the dowel pin which will be found at the upper end of the oil pump shaft.

2831. The diameter of the shaft hole in the oil pump body has been increased from $\frac{9}{16}$ to $\frac{5}{8}$ inch in diameter and the relief removed from the oil pump shaft.

The clearance between the shaft and body forms the oil passage through which the pump delivers oil to the valve chamber. Formerly, this clearance was obtained by relieving the shaft. The clearance is now obtained by boring a larger hole in the oil pump body and using a straight shaft.

When replacing shaft in an oil pump equipped with the relieved shaft be sure to replace it with the same type of shaft, as the present design straight shaft would not allow sufficient area for oil flow when mounted in the previous-design pump body with the $\frac{9}{16}$ inch shaft hole. The relieved shaft can, however, be used in the present pump with the $\frac{5}{8}$ inch shaft hole.

CARBURETOR

2832. To clean carburetor remove filter screen by backing out filter plug *A*, Figure 177, and blow out with air or rinse with gasoline. For complete cleaning, remove carburetor and disassemble by removing main assembly bolt *B*. Separate the parts carefully.

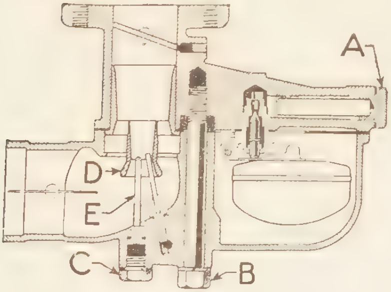


Figure 177

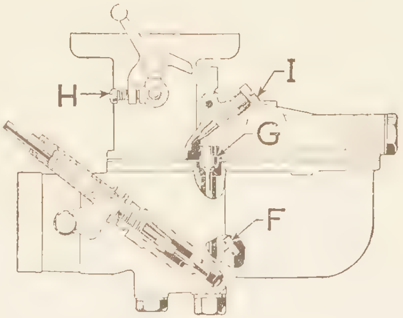


Figure 178

Figure 177.—The carburetor is taken apart by removing bolt *B*

Figure 178.—Carburetor showing adjustments

2833. Never replace a carburetor for complaint of poor idling or excessive gas consumption without first removing the carburetor and thoroughly cleaning the jets and filter screen. Also remove the brass plug beneath the main jet and thoroughly rinse the carburetor bowl with gasoline, using air to blow out any dirt which may have lodged in the bottom of the bowl.

2834. When removing the carburetor separate the parts carefully to avoid damaging the gasket, float, or idling jet tube.

2835. Carburetor Adjustment: For idling (when engine is limbered up), fully retard spark, adjust throttle stop screw *H*, Figure 178, so that engine will run fast enough to keep from stalling. Turn idle adjusting screw *I* until engine runs evenly; then back off throttle stop screw until desired minimum speed is obtained. Best idling will generally be obtained with the screw two turns off its seat. Dash adjustment does not control the entire fuel supply. A minimum amount of fuel is constantly drawn from the float chamber through small fixed openings even when the dash adjustment is fully closed. For best operation under usual driving conditions, the dash adjustment should be backed one-quarter turn off its seat, but a richer mixture may be required with a stiff engine. Less than one-quarter turn should be used for high altitudes, high-test fuels, or when driving at steady speeds on level roads.

2836. The carburetor choke lever has been redesigned to permit easy choking when cranking the engine by hand. This change consists of adding a hole at the end of the lever so that a wire or piece of twine can be easily attached for choking. (December, 1928.)

2837. Carburetor hints: In case of faulty carburetor action, see that secondary venturi *D*, Figure 177, is right side up as shown. If car lacks speed, see that main jet *E* is free from dirt. If engine runs badly at low speed and when idling, see if compensator *F* or idling jet *G*, Figure 178 is plugged.

2838. To determine whether the gasoline gage is sticking, rock the car vigorously. If gage dial oscillates, the gage is not stuck. If sticking, the gage can easily be removed by screwing out the flange nut using wrench 5-Z-1825. Wrench 5-Z-1822 is used for screwing out the cover to replace a glass. To prevent spillage, the gasoline tank should not be more than half full when removing gage.

Gasoline gages are built to register "Full" when the cork touches the top of the tank; a gallon of fuel remains in the tank when the gage shows "Empty." If the gage does not register as described, the float wire is bent. An easy way to check the gage is to remove the filler cap and screen and insert a wire hook to hold the float against the top of the tank. If the gage does not register "Full," the float wire should be bent accordingly. Sometimes a float wire is so badly bent it rubs against the filler screen, giving the gage hand a jerky movement.

2839. Although the outward appearance of the gasoline tank and radiator filler caps are the same, the inside construction of the caps is different. The gasoline tank cap has a vent hole drilled in the center of the raised portion which allows air to seep in through the six openings in the cap and prevent a vacuum forming in the tank.

Care must be exercised to see that the caps are not mixed. Should a radiator cap be screwed on the gasoline tank it would cause a vacuum to form in the tank and prevent the gasoline flowing to the carburetor.

2840. Several refinements have been made in the Model A carburetor which simplify and add to its smoothness of operation, especially at low speeds.

The original carburetor was provided with a double Venturi made up in two pieces. These parts have been replaced by a longer single Venturi (Figure 179), the narrowest part of which is 27/32 inch in diameter. Other changes consist in the addition of a secondary well which is screwed into the lower half of the carburetor as shown at *B* and from which the idling jet derives its supply.

A slight change has also been made in the angle of the throttle plate and the plate is now stamped No. 18½ instead of No. 20. The position of the cap jet in the lower half of the carburetor has also been slightly changed.

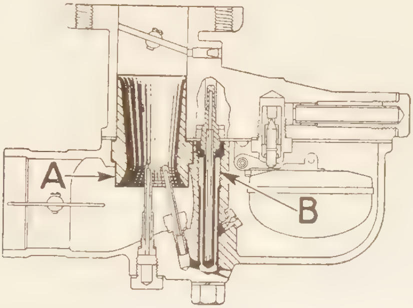


Figure 179.—Improved type of carburetor, showing changes

These changes necessitated using a different combination of fuel orifices, the parts being stamped as follows:

Main jet now stamped No. 19.5 instead of No. 20. The compensator is stamped No. 19 instead of No. 18. The cap jet is stamped No. 21 instead of No. 19. The idling jet No. 11 instead of No. 10.

The new idling jet is slightly shorter than the old one, the new jet being 3 inches overall—the old one $3\frac{5}{64}$ inches.

Never attempt to use old-style parts in the present carburetor. Although the parts look alike, the fuel orifices in the new parts have been changed to obtain maximum results.

2841. The previous instructions regarding carburetor cleaning and trouble checking remain unchanged with the exception that the breaker point gap should be set at 0.018 inch to 0.022 inch and the spark-plug gap 0.027 inch. It is important that all of the plugs be adjusted to a uniform gap of 0.027 inch.

2842. From enquiries received it is apparent that some owners still do not understand that after a Model A engine has been run in, the dash adjustment should not remain open more than ¼ turn except for warming up the engine. Owners should understand that it not only wastes fuel, but it is even harmful to leave this adjustment open longer than necessary.

COOLING SYSTEM

2843. Ford metallic water-pump packing is recommended for repacking the Ford pump. Do not remove the old packing. Simply cut off the required amount of new packing, wrap it on the shaft in the direction in which the nut turns, and draw up the packing nut. Do not tighten nut any more than necessary to stop the leak.

2844. Both the roller and plain bearings formerly used in the water-pump cover assembly have been replaced with A-8529 water-pump bushing front and A-8520 water-pump bushing assembly rear (April, 1929). These oilless bushings have eliminated the two lubricator fittings used in the water-pump assembly.

If occasion should arise where it is necessary to replace these bushings, new ones can be easily pressed into the cover assembly. Before pressing in new bushings be sure to fill the grooves in both ends of the cover assembly with a light grade of Alemite grease or its equivalent. To install the bushings an arbor press and special inserting plug and washer are used.

2845. To prevent any possibility of a water leak developing between cylinder head and block, make certain that cylinder head nuts on all new cars are pulled down tightly, particularly the cylinder head nut which holds down the ignition lock conduit.

IGNITION SYSTEM

2846. If trouble is experienced, check battery connections, yellow wire from terminal box to starting motor, black wire from terminal box to coil, and red wire from coil to switch. Also see paragraph 1155.

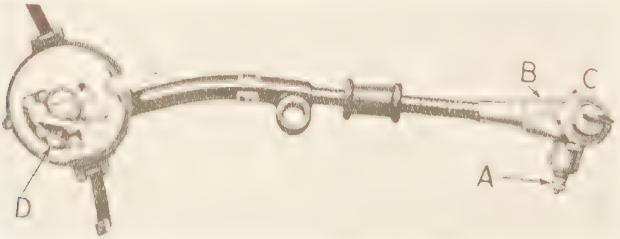


Figure 180.—Ignition switch and lock assembly

If these wires and connections are correct, check switch as follows: Remove the four screws which hold the instrument panel in place and pull panel back. Disconnect wire at terminal *A*, Figure 180. Then test switch as follows: First test: With breaker points in distributor open, place one test point on terminal *D,* Figure 180, and the other test point on terminal *A*. With switch unlocked the lamp should light; but should not light with switch locked. Second test: Place one test point on terminal *D,* and the other on switch casing *B*. With switch locked the lamp should burn but should not burn with switch unlocked. If lamp lights with switch locked on first test or if lamp lights with switch unlocked as in second test, either there is a ground in the switch or the condenser is shorted or grounded.

To remove condenser, remove sealing wax covering screw head *C,* Figure 181, and back out screw. Remove screw *A,* Figure 182, and remove condenser. Try a new condenser and repeat the second test.

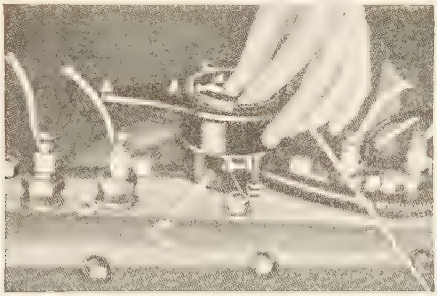


Figure 181.—Removing sealing wax from screw *C*

If the lamp still burns with switch unlocked the trouble lies in the switch and should be checked as follows: Unlock the switch and remove the three screws which hold the switch to the back of the instrument panel. The lock cylinder can then be removed by taking out set screw *C*, Figure 180. Test the contact buttons inside the switch housing to see that they are free and have spring pressure back of them. See that lock plunger is clean and that the

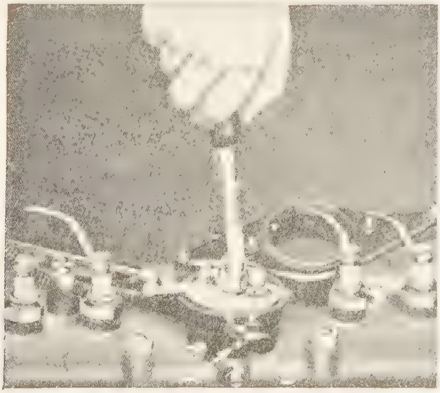


Figure 182.—Removing screw *A*

insulating washers are in place. If trouble is still unlocated the wire within the cable is probably broken and it will be necessary to replace the conduit assembly with the exception of the lock cylinder.

To remove switch or conduit assembly from car, remove bolt which fastens cable to engine, remove distributor from cylinder head and unscrew distributor from switch cable. Never grease or oil the lock cylinder. If the tumblers stick, place a little graphite in the keyhole.

2847. Breaker point gap is 0.015 to 0.018 inch. Points should be dressed with an oil stone; never use a file.

2848. To time ignition, fully retard spark lever; check breaker gap and adjust if necessary; screw out pin in timing gear cover and insert opposite end into opening; turn the engine over slowly while pressing in on the pin until pin slips into small recess in camshaft gear, indicating that pistons are on dead center. Remove distributor cover and lift off rotor and distributor body. Loosen cam locking screw, turn cam until breaker points are just ready to open, then tighten locking screw securely.

2849. The distributor breaker points should occasionally be checked to see that the points are clean, smooth and meet squarely. A point which is in good condition has a dull frosted appearance.

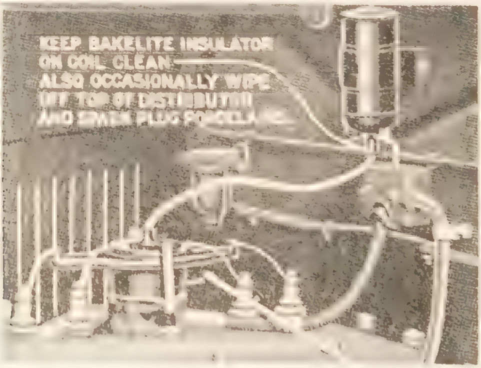


Figure 183.—Bakelite insulator on coil must be kept clean

2850. An examination of coils sent in by dealers as alleged defective material frequently show that the trouble experienced was entirely due to failure on the part of mechanics and owners to keep the bakelite insulator on the coil clean, Figure 183. After cleaning and scraping the insulator at the factory the coils invariably check 100 per cent.

2851. When dust and moisture are allowed to accumulate on the insulator, it sets up a path for leakage of the secondary current to ground instead of permitting the current to go on to the distributor and spark-plugs. In following this course, the current gradually forms a carbon path that resembles a crack in the insulator. By cleaning the insulator and scraping off the carbon with a sharp knife the coil will again operate satisfactorily.

2852. Another common cause of coil troubles is the failure of owners when shutting off the engine to push in on the cylinder of the electrolock far enough to permit it to snap back into the locked position. If the breaker points are closed when the lock is not all the way in, it permits the current to flow through the coil, causing overheating and consequent damage to the coil.

GENERATOR

2853. The winter charging rate is 14 amperes, and the summer charging rate, is 10 amperes. To adjust charging rate, remove generator cover, loosen third brush-holder lock screw, moving the brush in the direction of rotation to increase charging rate (Figure 184). To increase the charging rate, shift the field brush holder in the direction of rotation; to reduce the rate shift the brush in the opposite direction. The output of the generator is indicated by the ammeter on the instrument panel.

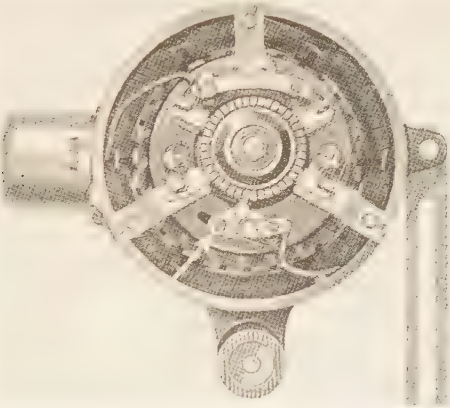


Figure 184.—Generator, showing third brush adjustment

2854. See that the generator commutator is clean. To clean the commutator use a narrow strip of fine sandpaper (not emery cloth). With the engine running hold the sandpaper against the commutator until commutator is clean and bright.

STARTER

2855. To insure proper meshing of starter pinion with flywheel ring gear, the distance or gap betwen the rear face of flywheel ring gear and front face of starter pinion must not be more than $^1/_{16}$ inch or less than $^1/_{32}$ (Figure

185). This gap can be regulated by means of shims (part No. A-11140 and 11141; these shims are $\frac{1}{64}$ and $\frac{1}{32}$ inch respectively).

To check the gap between pinion and ring gear, remove starting motor and measure the distance from machined surface at starter mounting opening in flywheel housing to rear face of flywheel ring gear. Then pull forward on starter drive pinion to take up any end play in armature assemble and measure distance from machined surface at the end of yoke to front face of starter pinion. The difference between these two dimensions is the gap. When removing the starting motor, time will be saved if the starting switch is detached instead of disconnecting the battery cable at the starting motor. After removing the switch, tie a cloth around it to insulate it against accidental contact with metal parts of the car.

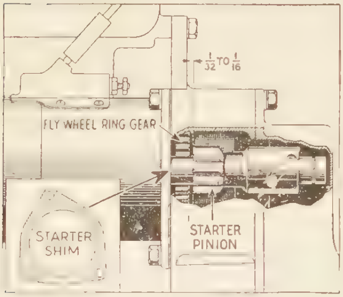


Figure 185.—Diagram showing meshing of starter pinion

2856. The starter switch assembly spring has been changed from an angular to a flat spring, and the top of the starter motor terminal machined flat instead of at an angle so that it will correspond with the spring. (October, 1928.)

The change in the switch necessitated making a slight change in the position of the battery to switch cable terminal, the terminal now extending straight out instead of at right angles to the cable as shown in dotted outline.

When replacing an old-style, starter-switch assembly with the present design switch, it will be necessary to file down the starter motor terminal until the top of the terminal is flat and extends $\frac{11}{32}$ to $\frac{3}{8}$ inch above the surface of the yoke. If the old style battery cable is used with the new switch it will also be necessary to bend the terminal so that it extends straight out. On the other hand, if a new cable is used with an old switch it will be necessary to bend the terminal at right angles to the cable.

BENDIX STARTER DRIVE

2857. On Model A cars and trucks in production since early October, 1928, the A-11350-C 8/10 pitch Bendix drive has been used. For this drive the starting motor armature shaft has a diameter of $\frac{5}{8}$ inch. This drive has a special form of 10 tooth pinion and we call your attention to the fact that it is not interchangeable with the standard 8/10 pitch 10-tooth pinion T-1885.

Complete starting motors, as now used on Model A production since October 1, 1928, can not be assembled on cars and trucks produced prior to that date, because of the change in the flywheel. Present starting motors with the 11350-C drive can only be used with the present design of flywheel.

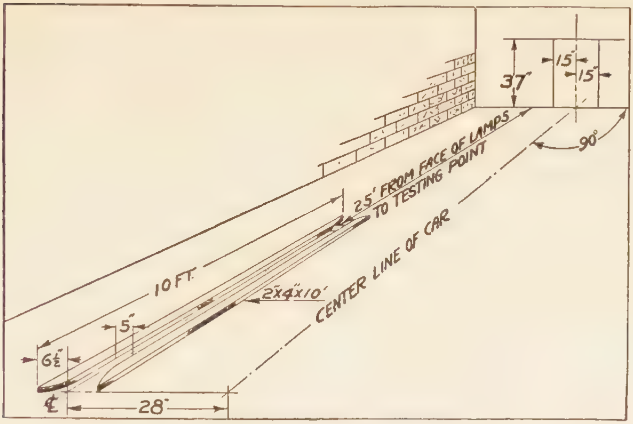

37"
15"
15"
90°
25' FROM FACE OF LAMPS TO TESTING POINT
10 FT.
2"x4"x10'
CENTER LINE OF CAR
5"
6½"
℄
28"

Figure 186.—Layout for focusing and alining new design head-lamp

HEADLAMPS

2858. To adjust headlamps, place empty car 25 feet from white wall or screen marked as shown in Figure 186. Turn on bright lights, cover one lamp and adjust the other by turning screw at rear, to obtain as good contrast and as well-defined cut-off across the top as possible (Figure 187). Treat the other lamp similarly. The center of the beam from one lamp should be 30 inches from the center of the beam from the other lamp. The beam from both lamps is shown in Figure 188.

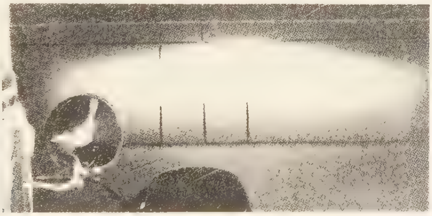


Figure 187.—Right head-lamp correctly focused and alined

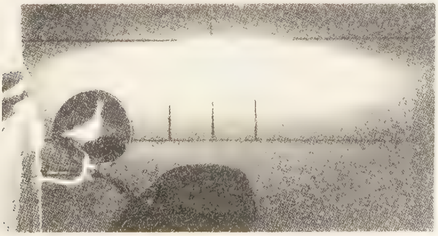


Figure 188.—Both head-lamps correctly focused and alined

CLUTCH

2859. To remove clutch it is first necessary to remove the rear-axle assembly (see paragraph 2880). Then proceed as follows: Disconnect front radius rod from clutch housing; disconnect stoplight switch; remove gear shifter housing by screwing out the 6-gear shifter housing screws; remove the 11-clutch housing screws; grasp the pedals and pull the clutch and transmission unit back.

2860. To separate clutch from transmission, remove cotter-pin and screw off clutch-shaft nut and withdraw clutch from shaft. To prevent the shaft from turning when screwing off clutch nut, lock the transmission gears by meshing the high and intermediate sliding gear with transmission main drive gear, and the low and reverse sliding gear with reverse idler. If clutch binds on its shaft when being withdrawn, push clutch pedal all the way down.

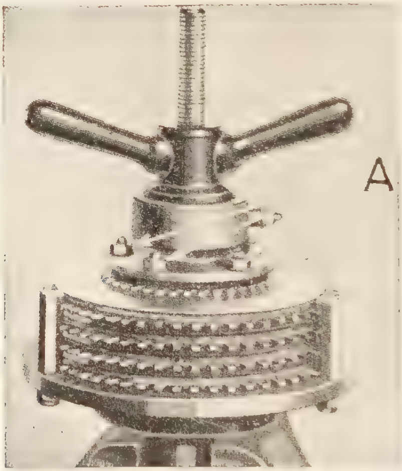


Figure 189.—Spêcial fixture for clutch disassembly

2861. To disassemble clutch, place clutch on special clutch fixture (Figure 189), and screw wing nut down until clutch spring tension is relieved; screw off the 5-clutch-driven disc stud nuts *A;* back off wing nut; lift out clutch thrust bearing hub and spring; to remove clutch plates, lightly drop the threaded end of the fixture on the bench, which act will remove all but the rear driven disc which is a tight fit on the drum and usually lasts the life of the car.

2862. To assemble clutch, place the rear driving disc over the clutch disc drum (the rear driven disc being in place on the drum). The rear driven disc must be a snug sliding fit on the internal teeth, having 0.002-inch clearance.

After installing the rear driving disc over the clutch disc drum place a smooth disc next to it, then a lined disc, and so on, finishing with a lined disc. The driven disc and stud assembly is inserted, the teeth in the disc and stud assembly meshing with the teeth in the drum. Place the clutch in fixture with studs pointing upward, making sure that the guides on the fixture mesh with the teeth in the clutch discs. Position clutch spring and thrust bearing hub over threaded shaft on clutch fixture and compress spring by tightening wing nut on fixture, and replace the 5-clutch-driven disc stud-lock washers and nuts.

2863. To hold the radius rod out of the way when installing clutch housing, insert a block of wood between radius rod and bottom of flywheel housing. See that pilot bearing in flywheel is well lubricated with cup grease.

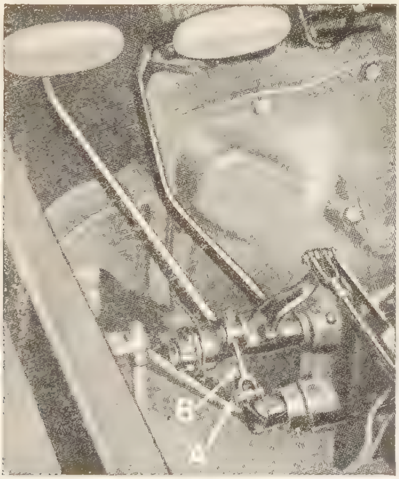


Figure 190.—Clutch pedal arrangement

Line up clutch housing with flywheel housing, and mesh teeth in clutch with teeth in flywheel. Bolt clutch housing to flywheel housing. Check clutch installation by removing clutch inspection plate, press clutch pedal all the way down and press in on the rear clutch disc (the one with the slotted tooth) to make certain that it is not binding on the internal teeth in the flywheel. Connect speedometer cable. Connect radius rod to clutch housing as described in paragraph 2911; reattach rear axle as described in paragraph 2881; replace gear shift as described in paragraph 2869.

2864. Clutch adjustment: The pedal should move about $\frac{3}{4}$ inch before it begins to disengage clutch. As the clutch wears, this movement will become less, and is brought back to normal by removing clevis pin *A* (Figure 190) and turning release arm *B*.

NEW CLUTCH

2865. The new single plate clutch now standard for Model "A" cars and "AA" truck is composed of two major units, namely the cover plate assembly A-7563 and the clutch disc assembly A-7550 or AA-7550 (Figure 191).

The cover-plate assembly consists of a cast-iron outer driving plate and a stamped cover plate in which are mounted 12 pressure springs and 6 release levers. These springs are in direct action against the pressure plate and automatically compensate for all wear of the friction facings. This feature eliminates any necessity of adjusting release levers.

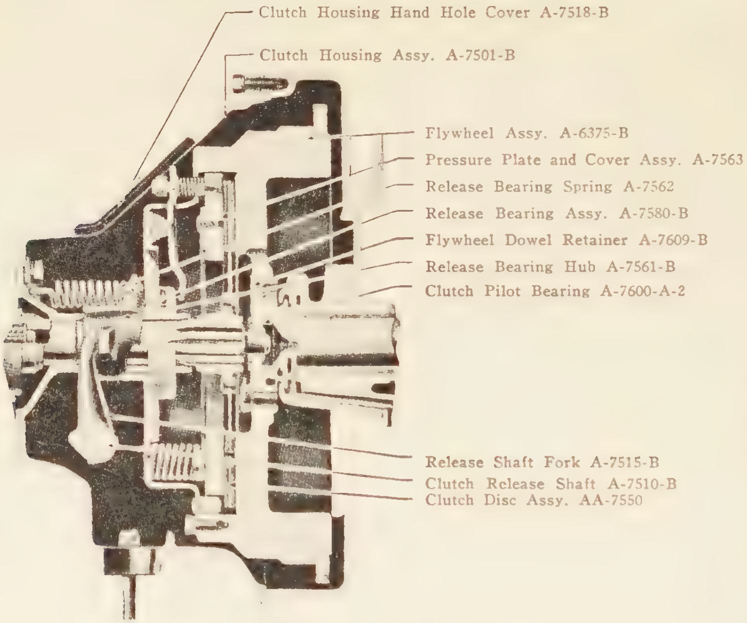

Clutch Housing Hand Hole Cover A-7518-B
Clutch Housing Assy. A-7501-B
Flywheel Assy. A-6375-B
Pressure Plate and Cover Assy. A-7563
Release Bearing Spring A-7562
Release Bearing Assy. A-7580-B
Flywheel Dowel Retainer A-7609-B
Release Bearing Hub A-7561-B
Clutch Pilot Bearing A-7600-A-2
Release Shaft Fork A-7515-B
Clutch Release Shaft A-7510-B
Clutch Disc Assy. AA-7550

Figure 191.—New single-plate clutch

The driven member or clutch disc assembly is composed of a flat steel disc and two friction facings. The facings are riveted to both sides of the driven disc. The disc is slightly dished in the form of a cone. With this construction the outer and inner edges of the clutch disc facings, start to engage first and as the clutch engages when the pedal is allowed to come back the spring pressure in the clutch flattens out the clutch disc and the entire lining surface picks up the load evenly. This feature assures exceptionally smooth clutch engagement.

Molded friction facings are used because of their long wearing qualities.

They also sucessfully withstand temperature as they contain no cotton element.

The only repair parts dealers will stock are the clutch disc assemblies A and AA-7550, clutch disc facings A-7549B and AA-7549, facing rivets A-22993 and pressure plate and cover assembly A-7563.

Should any part of the pressure plate and cover assembly fail, return the entire assembly to the Ford Branch, and a new assembly will be furnished at an exchange price of $4.25.

The pressure springs automatically compensate for all wear of the friction facings. Readjustment of the release levers must never be made under any circumstances.

The only adjustment for clutch wear is made at the bottom of the clutch pedal. The pedal must have 1 inch free-play or movement before it starts to disengage the clutch.

Grease on friction facings will cause the clutch to chatter during engagement or sometimes slip at high speeds. The remedy is to remove the clutch and install a new set of clutch-disc facings.

2866. Occasionally, due to an improperly adjusted clutch pedal or continuous abusive slippage, the clutch pressure plate may develop small radial heat crack. If the pressure plate is not grooved, and these cracks are not large, simply polish the face and replace the unit. These heat checks will cause no harm.

By increasing the diameter of the two pins used in fastening the arm and fork to the clutch release shaft, the two A-23901 keys which were also used at this point, have been eliminated. (June, 1929.)

The diameter of the new pin (A-23830) is $\frac{5}{16}$ inch, the old style pin (A-23732) was $\frac{3}{16}$ inch.

An increase in diameter of the pin $\frac{1}{8}$ inch made it necessary to increase the size of the pin hole in the clutch-release arm correspondingly also the shaft and fork.

When replacing an old design of clutch-release shaft with the new one, it will be necessary to increase the size of the hole in the old design arm to accommodate the new pin. It will also be necessary to install a new fork as there is not sufficient stock at that point to permit an increase in diameter of the pin hole in the old fork.

Instead of screwing out both clutch-housing hand-hole cover screws to remove the cover, remove only one screw and loosen the other; the cover can then be swung to one side.

When lubricating the clutch-release bearing, hold the clutch pedal all the way down. This prevents the bearing from turning while lubricating.

TRANSMISSION

2867. To disassemble transmission, remove gear-shifter housing. Disconnect clutch housing from transmission case by screwing out the 4-clutch housing-to-transmission-case screws. Lift off gasket, and withdraw main driveshaft and pilot bearing. Screw out the bearing-retainer-to-transmission-case screws and lift off bearing retainer and gasket. The main shaft complete with main shaft ball bearing and oil baffle can now be withdrawn and then the sliding gears may be lifted out. Remove countershaft and reverse-idler-shaft-retainer screw and lift off retainer. Remove countershaft by tapping it out of case. A hammer and brass drift is used for this purpose. Countershaft assembly can now be lifted out, the two countershaft bearings withdrawn from ends of shaft and the two countershaft gear thrust washers lifted out of housing. Next withdraw the reverse idler shaft assembly from housing, and lift out reverse idler gear.

2868. To assemble transmission, place reverse idler gear in case with the flush side of the gear to the rear of the case. Next insert reverse idler shaft through case and gear, turning it so that flat side of shaft faces countershaft hole in case. This lines up the shaft so that it can be locked in place when the reverse idler shaft retainer is installed. Place a little cup grease on the sides of the two thrust washers and position them in each end of the transmission case so that they line up with the countershaft holes in case. Next grease the two countershaft gear bearings—short and long—and insert a bearing into both ends of the countershaft gear assembly. The long bearing fits into the end of the small gear. After inserting the bearings into the ends of the countershaft gear assembly place the assembly in the case, meshing the small countershaft gear with the reverse idler gear. Next line up the two countershaft gear thrust washers and the countershaft gear assembly with the countershaft holes in the case and insert countershaft through washers and countershaft gear assembly. The shaft is tapped into place with a brass hammer. When installing, turn the shaft so that its flat side faces the flat side of the reverse idler gear shaft. Next, place the reverse-idler shaft retainer between the flat side of shafts and fasten it in place with lock washer and screw.

Line up the low and reverse-sliding gear with the transmission high and intermediate sliding gear, making sure that the faces of the grooved collars come together with the small gear to the front of the case. If a new main shaft or a high and intermediate sliding gear are to be installed select the parts so that the gear is a snug sliding fit on the shaft. The gear should have not more than 0.002-inch clearance on the shaft (check with feeler). The clearance may vary from 0.002 inch down to a point where the gear will just slide on the shaft of its own weight or with a slight pressure of the fingers when the shaft is held vertically. After lining up the gears insert the main shaft with ball bearing assembled. Place bearing retainer gasket on end of case and assemble main shaft bearing retainer gear case by installing the 4 lock washers and cap screws. These screws should be drawn down tight and wired. When installing retainer be sure it is assembled with the lubricator fitting pointing downward. Place pilot bearing over the end of the main shaft and collar assembly, then place main drive gear over bearing on main shaft, making sure that main drive shaft ball bearing seats in ball bearing seat in case.

Position clutch-housing-to-transmission-case gasket on end of transmission case and assembly clutch housing to transmission case by installing the 4 cap screws. Before installing the gear-shift housing see that the gear-shift housing gasket is in place on transmission case, the gear-shift lever in neutral position and the gears on the main shaft are spaced so that the gear shifter forks line up with the collars.

2869. Before installing the gear-shift housing see that the gear-shift housing gasket is in place, that shift lever is in neutral, and that gears are in neutral and properly lined. Place stoplight switch on gear-shift housing and bolt housing to transmission. Replace stoplight switch to brake pedal link and connect brake pedal to equalizer-shaft rod assembly.

TRANSMISSION SHAFT AND GEARS

2870. The intermediate and high sliding gear and the low and reverse sliding gear are now fitted to exceptionally close limits on the transmission main shaft; in addition, the parts are selectively assembled. This procedure ensures extremely accurate fitting and it eliminates any possibility of the gears coming out of mesh. (December, 1928.) Due to the close limits to which these parts are held it will be necessary when installing new shaft and gears to assemble the parts by selective fit.

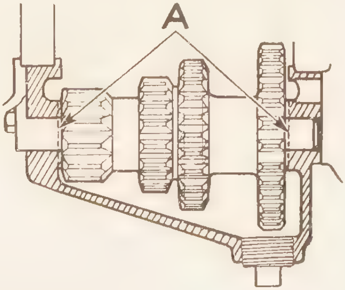


Figure 192.—Change in transmission case

2871. A change has been made in the transmission case which eliminates the two A-7119 transmission countershaft gear thrust washers in the present design case (January, 1929). This has been accomplished by increasing the thickness of the countershaft gear bosses to correspond with the thickness of the A-7119 washers removed (Figure 192).

The new design case can be readily distinguished from the old one by checking the distance between the bosses. An easy way to do this is to place a countershaft between the two bosses in the case and note the clearance between ends of shaft and bosses. If it is the new design case there will be only a few thousandths clearance between ends of shaft and bosses and the A-7119 washers will not be used. If it is an old design case there will be more than ⅛-inch clearance and it will, of course, be necessary to use the washers when installing countershaft gear assembly.

RETAINER AND OIL BAFFLE

2872. To reduce any possibility of oil leakage through the rear transmission bearing, a flange has been added at the center of the A-7085-A1 transmission main shaft bearing retainer, which changes the diameter of the hole in this part from 2½ inches to 1 27/32 inches. The dotted lines at the bottom of the retainer show where the new flange extends (Figure 193).

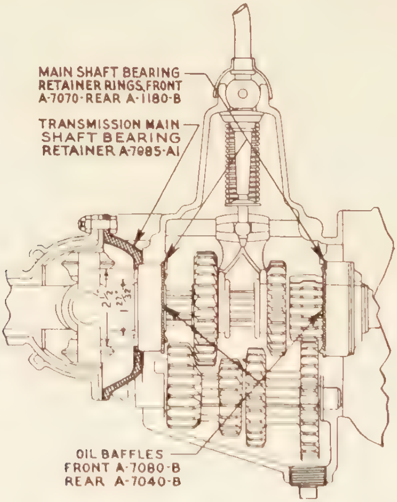

MAIN SHAFT BEARING RETAINER RINGS, FRONT A-7070-REAR A-1180-B
TRANSMISSION MAIN SHAFT BEARING RETAINER A-7085-A1
2½
1 27/32
OIL BAFFLES FRONT A-7080-B REAR A-7040-B

Figure 193.—Changes in transmission

To reduce further any possibility of leakage, new front and rear transmission main shaft bearing oil baffles A-7040-B and A-7080-B have been released. The new baffles are ⅛ inch larger in diameter than the old ones. They can be installed in all transmission cases equipped with main shaft bearing retainer rings A-7070 and A-1180-B (Figure 193). In the early cases these rings were not installed, as the machined shoulders in the transmission case served as bearing stops. In the later cases the machined shoulders were replaced with the present design retainer rings.

If occasion should arise where it is necessary to replace the oil baffles in one of the early design cases, install the A-7040-A and 7080-A baffles. If the transmission case is equipped with retainer rings, install the B design baffles. The new retainer A-7085-A1 can be used with either the old style or present design transmission case.

BRAKES

2873. All adjustments should be made with brakes cold. Jack up all four wheels, release hand brake lever and see that wheels revolve freely. Turn the adjusting wedge at each brake (not the pull rod) until the brake drags slightly, then back off the wedge two or three notches, or just enough to permit the wheels to revolve without drag. On new cars, the brakes will sometimes drag slightly for ¼ or ½ revolution due to small high spots. Some judgment must be used in setting such brakes, for if the drag is entirely removed, the brake pedal will go all the way to the floor board when the brakes are hot. A slight drag in one or two spots will do no harm as the drag will be removed after the car is run a short distance and the drums become warm. It is for this reason that brakes should not be adjusted when drums are hot. If adjustments have been correctly made, the brakes should operate as follows: Rear brakes should just begin to hold when the pedal is depressed approximately 1 inch; depressing pedal ½ inch farther should tighten but not lock the rear brakes and cause front brakes to begin to take hold. Depressing pedal another ½ inch should lock rear wheels and hold front wheels tightly. At this point, pedal travel should not exceed one-half of total. When pedal is applied with full pressure, the rear wheels should slide and the front wheels should make a heavy impression on the road.

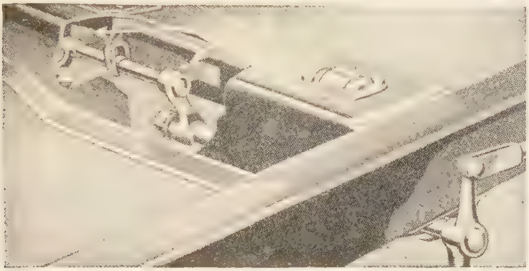


Figure 194.—Brake equalizer

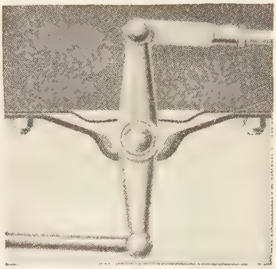


Figure 195.—Cross-shaft

2874. The length of the brake pull rods connected to the levers at each brake are correctly set at the factory and should not be altered. If the pull rods have been tampered with in an attempt to adjust the brakes, readjust them as follows: Operate the brake pedal quickly, snapping it on and off several times to insure the brakes being fully released. Disconnect the pull rods at the adjustable clevises by removing cotters and clevis pins. Make certain that the brake equalizer levers under the center cross member are back against the stops, *A* (Figure 194), and the brake cross shaft is in the center of its travel as allowed by the bracket on the frame side member (Figure 195). An easy way to keep the cross shaft in the center of the bracket while the adjustment is being made is to insert a wooden wedge between the bracket and each side of the shaft. With the brake equalizers against their stops, and the brake cross shafts in the center of their brackets as just described, pull forward on the rear brake rod just sufficiently to take up the free travel in the rear brake lever, then adjust the clevis until the holes in the clevis line up with the hole in the cross-shaft lever and the clevis pin can be inserted.

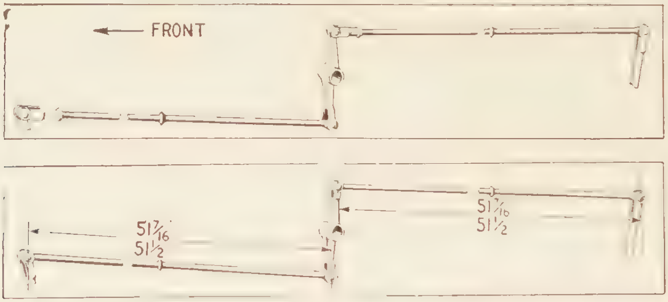


Figure 196.—Former (upper) and present (lower) design of brake rods

2875. The model A later, July 1928, was fitted with non-adjustable brake rods, new and old constructions being shown in Figure 196. To install a new brake rod on a car equipped with adjustable rods, saw off the end of the rod ¼ inch back from the center of the eye, and run a 5/16-24 thread back 2 inches. The length of the rod should be adjusted to not less than 51 7/16 or more than 51½ inches.

2876. A one-piece brake cross-shaft assembly has also been adopted (A 2485 6 C) superseding the former design in which the shaft and end levers were individual items. Should it be necessary to replace a brake cross-shaft assembly A-2485 or 6-AR, install the latest type cross-shaft assembly A-2485 or 6-C, together with the solid-type rear rod.

ADJUSTING EMERGENCY BRAKES

2877. The new emergency brake (Figure 197), which is entirely separate from the service brake is adjusted as follows:

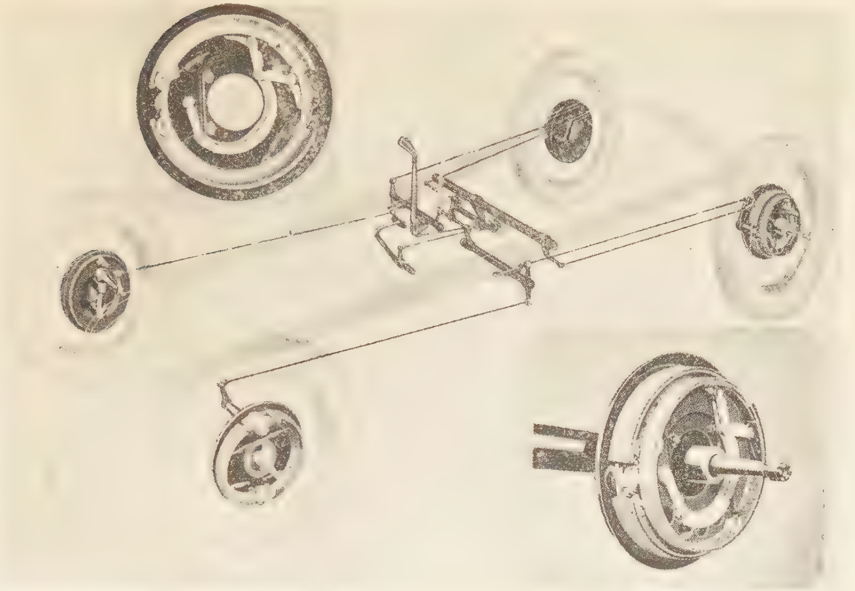


Figure 197.—Model A service and emergency brakes

(a) Fully release emergency brake lever.

(b) Remove rod A-2853 that connects emergency brake lever to cross-shaft center lever (Figure 198).

(c) Next replace the rod inserting it through hole *B* in center cross member and connecting the rod to the cross-shaft center lever through upper hole *C* in lever. (Never adjust for wear by shortening the pull rods.)

2878. The length of the pull rods that connect the emergency brake

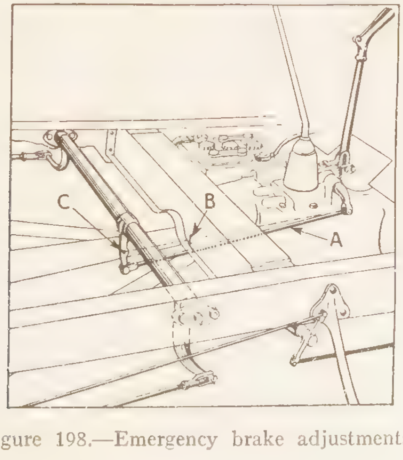


Figure 198.—Emergency brake adjustments

cross shaft to operating lever are correctly set at the factory and will rarely require further attention. If occasion should arise where one wheel slides before the other when the emergency brake is applied, the brake can be equalized as follows:

(a) Make all adjustments with brakes cold.

(b) Fully release emergency brake lever placing it in the extreme forward position.

(c) Jack up rear end.

(d) Disconnect both emergency brake pull rods from emergency brake cross shaft end levers.

(e) Rotate both rear wheels to see that service brakes are not dragging. If dragging readjust service brakes.

(f) Next, turn the adjustable end of both brake pull rods until eye in end of rod is exactly in line with end of cross shaft end lever, and rod can be slipped freely over end of lever. Then assemble rods to levers and check adjustment as follows:

(g) With the car traveling 15 to 25 miles an hour on a dry paved surface, slowly apply the emergency brake with a gradually increasing hand pressure, having an observer note whether both wheels slide at the same time. If properly adjusted, both rear wheels will lock evenly when the emergency brake lever is applied.

If one wheel locks before the other it will be necessary to readjust the brake that locks first; this is done by backing off the adjustable end of the emergency brake pull rod approximately two turns and then repeating the test. If the same wheel still locks first, shorten the pull rod on the opposite brake until a uniform brake action is secured.

(h) After making final adjustment, make sure that all clevis and cotter-pins are in place.

REAR AXLE

2879. There are no adjustments. The differential assembly can be removed after removing left axle housing.

2880. Rear axle assembly is removed as follows: Disconnect rear shock absorbers by removing nut and withdrawing shock absorber arm and clamp bolt, then shock absorber arm can be withdrawn; remove spring hanger by screwing off nuts and tapping the hanger out with hammer and drift; disconnect rear brake rods at cross shafts; take out mat and floor boards and remove battery; disconnect speedometer cable at speedometer drive cap, being careful not to bend the cable to a radius of less than 7 inches; jack up rear end of car; remove the 6 universal joint housing cap to transmission bolts, then remove the upper and lower halves of the universal joint housing caps, and withdraw the rear-axle assembly; lift off the inner universal joint housing cap.

2881. To replace rear axle, place axle assembly under car and insert drive shaft into universal joint. Place upper half of universal joint housing over universal joint housing. Make certain that the equalizer beam and the ends of the cross shafts are thoroughly greased and that the brake cross shaft socket springs are in the end of the brake cross-shaft assemblies. Attach the lower half of the universal joint cap, and install the six bolts, nuts and cotter keys. Attach rear spring hanger and bars, placing blocks of wood under the ends of the springs and using a spring compressor. Replace shock-absorber arms, drawing the nuts down tightly.

2882. The rear-axle shaft, drive shaft, and rear wheels grease retainers (part numbers A-4245 and A-1175), must always be installed with the sharp edge of the leather section of the retainer pointing toward the part from which the grease would flow. In other words, the rear-axle shaft grease retainer must be installed with the sharp edge of the leather section of the retainer pointing toward the differential (Figure 199). The drive-shaft grease retainer must be installed with the sharp edge of the leather section of the retainer pointing forward on the drive shaft (Figure 200) and the rear wheel grease retainer must be installed with the sharp edge of the leather section of the retainer pointing toward the bearing in the rear hub (Figure 199).

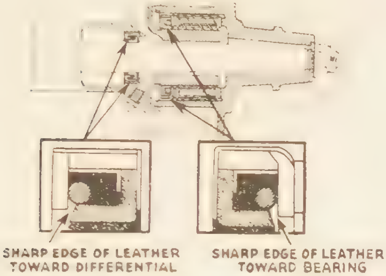

SHARP EDGE OF LEATHER TOWARD DIFFERENTIAL
SHARP EDGE OF LEATHER TOWARD BEARING

Figure 199

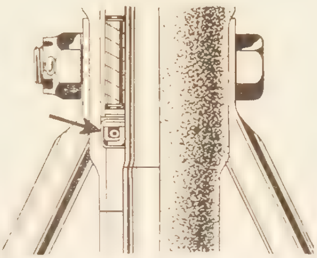


Figure 200

Figure 199.—Method of installing rear-axle grease retainers

Figure 200.—Correct installation of grease retainer at front end of drive shaft

2883. When a rear-end grease leak develops, check the lubricant level in the axle and make certain that the grease retainers are correctly installed; also that the retainer shell is a tight fit in the housing so that the leather will remain stationary and not revolve with the shaft.

2884. The splines on the end of the AA-4605 drive shaft and AA-7090 universal joint have been re-designed (August, 1929). The new splines are slightly shallower than the old design. This changes the diameter of the splines in these parts. When replacing an old drive shaft with one of the new shafts with the shallow splines, it will be necessary to install a new universal joint with the $\frac{1.083}{1.085}$ splines, as the old style universal joint can not be used with the new style drive shaft. Old style drive shafts can, however, be used with the new universal joint. In addition to the difference in the width of the splines, it will also be noted that the splines on the old drive shaft are rounded on the bottom, whereas those on the new drive shaft are square.

2885. Before installing a puller to remove rear hub and brake drum assembly, remove axle-shaft nut, and screw it onto the axle shaft with the castles on the nut pointing inward. The nut should be screwed down until it is flush with end of shaft, then apply puller in the regular way. The placing of nut on the shaft prevents mushrooming or swelling end of the shaft when pulling it off the drum.

2886. The new A-1015AR wheel is designed for use only with A-1105AR and A-1115AR hub and brake drum. The A-1015B wheel is designed for use with A-1105B and A-1115B hub and brake dum (March, 1929). Under no circumstances must an AR wheel be used with a B hub or the reverse. Use of an AR wheel with a B hub leaves a space between wheel shell and brake drum, thus losing the stiffness that this assembly should have. Use of a B wheel with an AR hub does not allow sufficient threads on the hub bolts to project through the wheel to permit the wheel nuts to be securely tightened.

SHOCK ABSORBERS

2887. Shock absorbers marked CW (clockwise) should be installed at right front and left rear. Shock absorbers marked AC (anti-clockwise) should be installed at left front and right rear. For average use the pointer should be set at 2 for front shock absorbers and 3 for rear shock absorbers. Resistance is increased as needle valve is moved from 1 to 8. During extremely cold weather it may be advisable to decrease the resistance to 1. Commercial glycerin with 10 per cent alcohol is the liquid used, and the level should be examined every 5,000 to 10,000 miles. In warm climates replenish with glycerin only. Where temperature is below zero add ½ to 1 ounce of alcohol.

2888. The shock absorber, clamp-bolt nut must be kept secure at all times. Make this a part of your regular inspection.

2889. The pointer on the shock absorber needle valve has been removed and the end of the valve squared. (September, 1928.) The numerals which were stamped on the shock-absorber arm have also been removed as they are no longer required.

2890. Turning the squared end of the valve changes the adjustment. Resistance is increased when the needle valve is screwed in and decreased when the valve is backed out. The average adjustment for rear shock absorbers during warm weather is made as follows: Screw needle valve in until it seats, then back valve off ¼ turn. For front shock absorbers, back valve off ⅜ turn. For cold-weather adjustment the needle valve in the rear shock absorbers should be screwed in until it seats, then backed off ½ to ⅝ turn. For front shock absorbers the needle valve should be backed off ⅝ to ¾ turn. These settings are of course only approximate and can be easily changed to suit the individual preference of the owner and the conditions under which the car is operated. For example: the owner who drives at high speed over rough roads would require greater shock-absorber resistance than the owner who drives at moderate speed over paved highways.

STEERING GEAR

2891. End play in the steering gear shaft is taken up by removing one or more brass shims placed between the steering shaft lower bearing assembly and the end of the housing. End play in the sector shaft is removed by loosening the lock-nut and lightly turning the steering worm sector thrust screw shown in Figure 201.

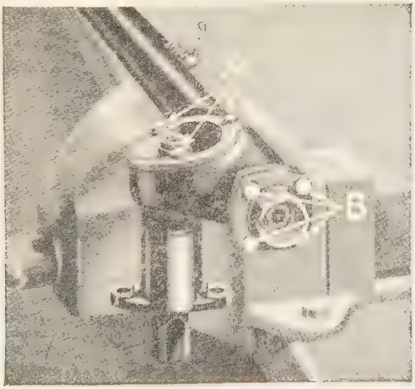


Figure 201.—Steering-gear adjustments

2892. The steering gear is removed as follows: Disconnect spark and throttle rods and remove lighting switch by unsnapping lighting switch bail, lifting off lighting switch and wire assembly. Press upward on operating spider and lift out spider retainer. Spider and spring will then slip off of shaft. Withdraw lighting switch handle and horn switch assembly, screw off steering wheel nut, and withdraw wheel from shaft. Screw off clamp bolt on drop arm and withdraw arm by tapping it off of sector shaft. Remove the two bolts holding the steering gear housing to the frame. Take out mat and floor boards, disconnect battery cable, pushing the cable to one side so that it will not interfere when the assembly is withdrawn. Screw out the two steering column support screws and lift off support. Steering gear assembly may now be withdrawn from front end of car.

2893. Place steering gear in vise. Remove housing cover by running out cap screws (Figure 201), drain lubricant, remove steering shaft lower bearing assembly by running out the four cap screws *B*, and withdraw assembly from housing. Do not misplace the brass shims which come off when the assembly is removed. Withdraw worm sector (Figure 202). Remove steering shaft by tapping it out with a brass or lead hammer. To prevent damaging the threads start a nut on the end of the shaft. When the shaft is withdrawn, the lower bearing will come with it, and then the upper bearing can be lifted out. To remove the control rod levers and springs, drive out the control rod pins, after which the control rod levers and springs can be slipped from the ends of the rods. Spark and throttle rods con then be withdrawn from steering shaft upper bushing. The anti-rattlers on the spark and throttle rods will drop off inside the housing when the rods are withdrawn and must be recovered by tilting the housing.

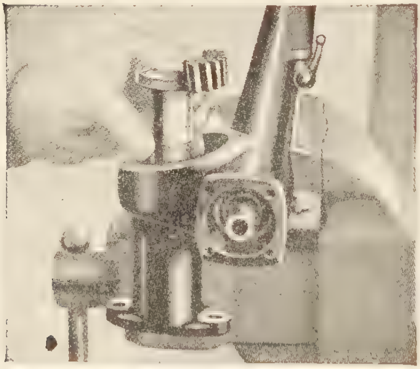


Figure 202.—Removal of steering sector

2894. Parts should be washed in kerosene and carefully examined, and the bushings in the housing should also be inspected. New gaskets will usually prove more satisfactory. Inspect each gasket before installing, and see that the surfaces it fits against are in good condition. Before assemblying, thoroughly lubricate all parts.

2895. To assemble steering gear, insert spark and throttle rods through steering shaft upper bushing, then slip the two anti-rattlers over the ends of the rods, sliding them back until they come into contact with the two small notches on the rods. Insert this assembly into steering gear housing; tap the bushing down until the screw holes in the bushing line up with the screw holes in the housing, making sure that the ends of the spark and throttle rods slip into the openings. Then replace the two steering column tube screws. Replace the control rod springs and levers, being careful to rivet the pins tightly. When installing the levers be sure that the ball end of the lever to which the throttle rod is attached points upward, while the ball end of the lever to which the spark rod is attached points downwards. Slip the worm-shaft upper thrust bearing over the end of the shaft, sliding the bearing down until it rests against the worm. Then the shaft is inserted into the housing until the front end of the shaft enters steering shaft upper bushing and the worm rests against the upper thrust bearing. Insert lower bearing over end of steering shaft. Place steering shaft lower bearing shims over lower bearing assembly, replacing same number of shims of same thickness as were removed. These shims are made in three thicknesses 0.0025, 0.005 and 0.010 inch, and are used to take up end play in the steering shaft.

The lower bearing assembly is inserted into the gear housing and bolted in place. Make sure that the 3/16-inch oil hole has its open end toward the top of the steering gear. Place worm-sector thrust washer over end of sector with notched side of washer toward toothed end of sector, and mesh sector with worm. Place steering gear housing on its side and fill with steering gear lubricant. It holds about 7¾ ounces. Replace steering gear housing cap and gasket. The steering wheel should now be placed on the shaft, and the assembly checked to be sure that it turns freely and adjustment is satisfactory. Wheel should not have more than 1-inch play. If adjustment fails to correct the trouble, install a new sector.

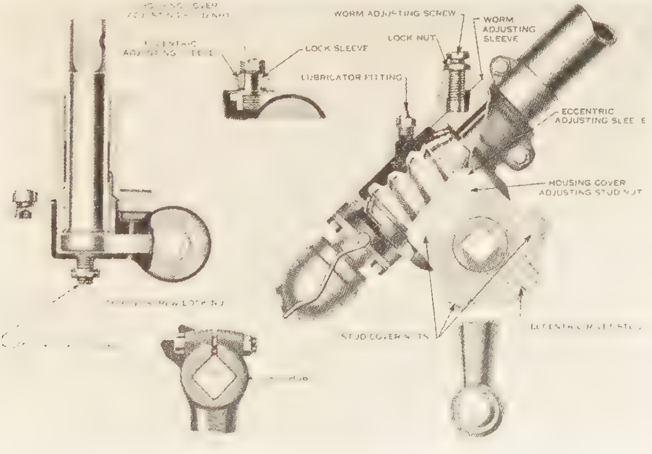


Figure 203.—New steering gear

NEW STEERING GEAR

2896. Some Model A cars are now equipped with a new design steering gear (Figure 203), (February, 1929).

2897. When making adjustments, the front wheels of the car should be jacked up and the drag-link disconnected from steering arm in order to effect a satisfactory adjustment.

2898. There are three adjustments which can be made with the steering gear assembled in the car, namely: End play in worm sector; end play in steering shaft; proper mesh of sector teeth in worm. When it is necessary to make any one of these adjustments, the other two adjustments should also be checked. Adjustments should always be checked in the following order:

2899. First see that housing cover nuts are securely tightened. Next turn steering wheel to either extreme, then back 1/8 turn. Gripping steering arm at hub, the shaft should move freely when turned back and forth, without any end play. Adjust as required by means of sector thrust screw at side of housing next to motor (Figure 204). A special offset screwdriver is required for this purpose. After making adjustment, be sure to tighten lock-nut, then re-inspect for end play and freedom.

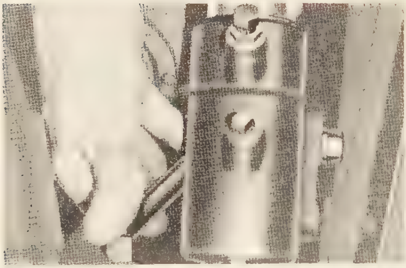


Figure 204

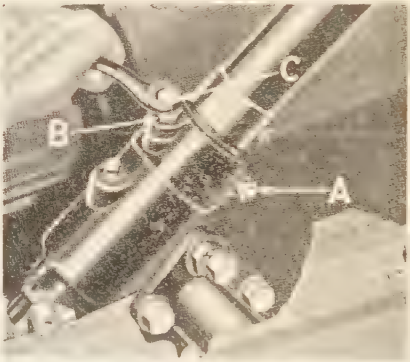


Figure 205

Figure 204.—Sector thrust screw adjustment
Figure 205.—End-play adjustment

2900. To adjust for end play in steering shaft or between worm and roller bearing thrusts, turn steering wheel to either end stop, then back up 1/8 turn, or to a point where there is lash of steering arm. This leaves the steering shaft bearings free of side thrust. Next loosen housing clamp bolt (see *A*, Figure 205), and lock-nut *B*, on worm adjusting screw *C*. Turn down adjustment screw tightly with a 6-inch wrench, then back off 1/6 turn. Next tighten lock-nut and housing clamp bolt securely. Turn steering wheel from extreme to extreme positions and test for stiffness.

2901. Turn steering wheel to the mid-position of its complete travel or turning limits. (Drag-link previously disconnected.) Shake steering arm to determine amount of lost motion. Next loosen the three housing cover stud nuts exactly 1/4 turn, then loosen housing cover adjusting stud nut (Figure 206), 1/2 turn. Turn the eccentric adjusting sleeve *A*, clockwise, very gradually, checking at each movement the amount of lost motion still existing at the steering arm. Adjust only sufficiently tight to eliminate all lash of steering arm (no more), being sure to finish movement of eccentric adjustment sleeve *A* in clockwise direction. Turn steering wheel throughout full travel to test for free operation. If too tight, turn eccentric adjusting sleeve *A* counterclockwise to free and readjust, as above, more carefully. Next, tighten housing cover adjusting stud nut securely, and follow by tightening housing cover nuts. It is important that the adjusting stud nut be tightened before tightening housing cover nuts.

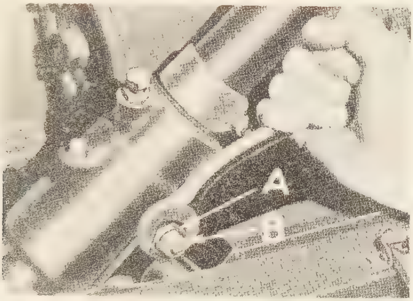


Figure 206.—Loosen the three other nuts on this plate and then adjust as shown

2902. The foregoing adjustments will suffice in nearly every instance. Occasionally, however, even after all three of these adjustments have been carefully made and checked, there may still be an unequal amount of lash between sector teeth and worm at points equi-distant from central position of worm. To compensate for any unequalities in lash, an eccentric rivet adjustment is provided. By means of this adjustment the sector shaft can be shifted to either side of the worm centerline. To make this adjustment, however, it is necessary to remove the steering gear assembly from the car.

FRONT WHEELS

2903. When adjusting front wheels, (1) see that front hub, inner and outer bearings are packed with grease. (2) Front hub grease retainer and lock washer should slide over threads on spindle body with fingers (loose fit). (3) Install nut, tighten same so that all component parts are pulled together snugly—that is, inner and outer bearings will be snug in cones, lock washer tight against roller bearing, and nut tight against lock washer. Grasp drum at top and bottom, apply side strain; see that bearings are tight in wheel hub with no side play. (A slight drag will be noticeable when drum is turned.) Not more than 8- or 10-pound pressure is required on speed wrench to get these results. (4) Turn nut back two castle slots (this is approximately

$\frac{1}{4}$ turn of nut); insert cotter-pin and try bearings for a slight side play and a free spinning wheel.

2904. A new tapered locking pin A-3122-C is now being used on both the car and truck. The new pin holds the spindle bolt more securely and prevents any possibility of the bolt working loose in service. When installed on a car, nut A-3124 must be used with the pin. When installed on a truck use nut AA-3124. To prevent affecting the turning radius of the car and truck, it is essential that the correct nuts be used with the pin. The AA-3124 nut can be easily distinguished from the A-3124 as it is approximately $\frac{1}{8}$ inch longer (Figure 207). The old locking pin A-3122-B will be held for repairs.

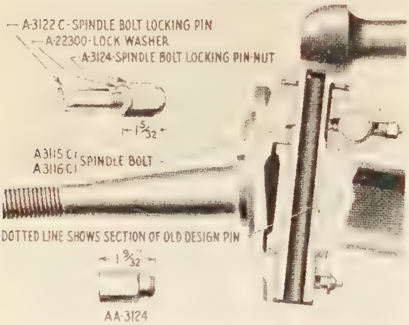

A-3122 C-SPINDLE BOLT LOCKING PIN
A-22300-LOCK WASHER
A-3124-SPINDLE BOLT LOCKING PIN-NUT
1 5/32
A3115 C
A3116 C
SPINDLE BOLT
DOTTED LINE SHOWS SECTION OF OLD DESIGN PIN
1 9/32"
AA-3124

Figure 207.—New spindle construction

To accommodate the new pin, a slight change has been made in the spindle bolt and as the old spindle bolts A-3115-16-B will not be held for repairs, it will accordingly be necessary, when replacing the old design B bolt with the present design 3115-16-C bolt, to install pin A-3122-C, nut A or AA-3124 and washer A-22300.

2905. Front wheels should have a toe-in of $\frac{3}{16}$ to $\frac{1}{4}$ inch (See *A* and *B*, Figure 208), and a camber of approximately $1\frac{13}{16}$ inches. (See *C* and *D*, Figure 209.) The best way to check toe-in measurements is with a wheel alining gage.

2906. Pull car forward at least 3 feet before placing gage in position. Place gage between front wheels with ends of gage bearing against the tires and both pendant chains barely touching the floor. (Figure 210.) An owner may approximate this device by using two sticks held together with

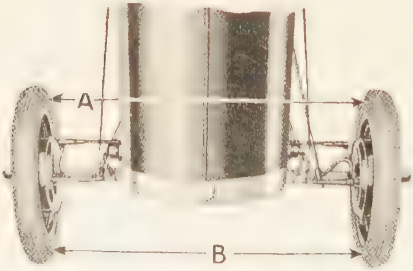


Figure 208

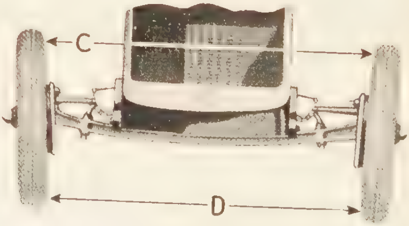


Figure 209

Figure 208.—Toe-in is distance *A* minus distance *B*

Figure 209.—Camber is distance *C* minus distance *D*

rubber bands. Front and rear measurements for toe-in should be made 8 inches from the floor. Test for play in bushings by pressing outward on the front of both front wheels at the same time. Set the scale on the gage so that the pointer registers a zero; then with gage still in place, move car forward until gage is brought to a position back of the axle with both pendant chains barely touching floor. The pointer will now register the exact amount of front wheel toe-in.

2907. To adjust the toe-in remove cotter-pins and loosen the two spindle connecting-rod end clamp bolt nuts; then turn the spindle connecting-rod either in or out until the correct adjustment is obtained. The rod has a right-hand thread on one end and a left-hand thread on the other which simplifies adjustments. When the correct toe-in is obtained, tighten the two connecting-rod clamp bolt nuts, making sure to replace cotter keys.

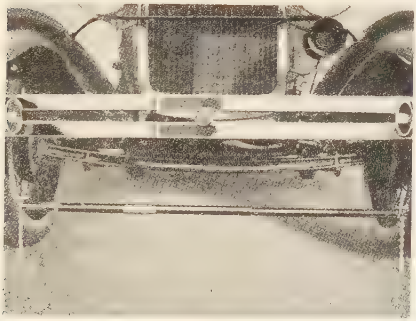


Figure 210.—Wheel alining gage

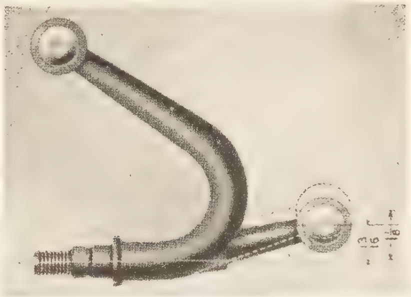


Figure 211.—Change in spindle arm

2908. Front wheel toe-in has been changed from $\frac{3}{16}$ to $\frac{1}{16}$ inch, plus or minus $\frac{1}{32}$ inch. This new adjustment insures maximum front tire life (September, 1928).

2909. Spindle arms A-3130-B and A-3131-B have been changed—that is, the distance between center line of shoulder (which fits in the spindle) and center line of ball has been changed from $1\frac{1}{8}$ inches to $\frac{13}{16}$ inch (Figure 211). The distance between the shoulder and ball has also been changed from $4\frac{7}{8}$ to $4\frac{15}{16}$ inches. These changes in the spindle arm reduce front tire wear to a minimum when turning corners.

CAMBER NOT ADJUSTABLE

2910. The camber is not adjustable because it is provided for in the forging of the spindle. The only possibility of the camber being changed would be due to a bent axle or spindle or badly worn spindle body bushing.

2911. When connecting the ball end of the front radius rod to the clutch housing, it is very important that the ball cap bolt sleeve (A-3435) is in place on both radius rod ball cap bolts. The sleeves prevent the ball cap springs being fully compressed when the ball cap nuts are tightened. If the sleeves are not in place, the radius rod ball will be clamped solidly between the ball caps, thus preventing it from having its natural motion with the action of the front springs. This condition throws a heavy strain on the end of the rod where the ball is attached and may cause a fracture at that point.

2912. The front radius rod is connected to the clutch housing as follows: Slip radius rod ball socket over ends of ball cap bolts. Place a little cup grease on radius rod ball and insert ball into ball socket. Place bolt sleeves over ends of ball cap bolts and position ball cap over sleeves and against ball. Next insert the two ball cap springs over the sleeves and run down the two ball cap nuts sufficiently far to permit locking them in place with cotter keys.

CHANGE IN METHOD OF INSTALLING DRAG-LINK

2913. To provide additional clearance between drag-link and front-brake shaft housing, the end of the drag-link, which was formerly assembled to the rear, is now assembled to the front. This necessitated replacing the lubricator fittings so they would be easily accessible when the position of the drag-link was reversed.

When installing a new drag-link, note that on one end of the drag-link the opening for the ball arm is approximately $\frac{3}{8}$ inch from the end of the drag-link (this end must be assembled to the spindle arm). On the opposite end the opening is approximately $1\frac{3}{8}$ inches from the end of the link (this end is assembled to the steering gear arm).

WINDSHIELD WIPER

2914. Proper wiping depends on the condition of the edge of the blade and on the tension adjustment. The edge must be smooth, straight and free from oil. The tension should be sufficient to prevent chatter but not enough to bend the rubber against the glass. The tension is adjusted by the small knurled nut where the spring arm connects to the driving lever. Circular streaks are caused by: (1) frayed edge of rubber blade; (2) irregular edge; (3) bent blade; (4) oil or grease on windshield or rubber. The blade should turn readily at each end of the stroke; if it fails to turn it will chatter. If blade chatters on one side only it indicates that it is turning too far in the spring arm. The opening in the lower end of the spring arm should be $\frac{5}{32}$ inch (Figure 212). The blade should turn an equal

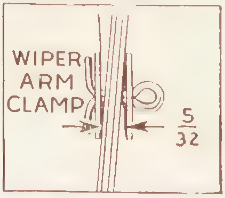


Figure 212.—Windshield wiper blade adjustment

amount at each end of stroke. Tension too great will prevent blade from turning.

To detect the trouble in the action of the windshield-wiper driving mechanism, note that when the switch is on the ammeter should show a small discharge. If the wiper does not start and the ammeter shows no discharge, it indicates an open circuit. Swing the windshield to its outer position and examine the terminal at the wiper, making sure that the connector snaps firmly over the terminal. If a test shows that current is being delivered to the connector, check the ground connection on the wiper by holding one end of a piece of bare wire against one of the nickelplated screws and the other end against any clean metal part on the windshield frame. If ground connection is faulty, remove wiper and clean the surface underneath. If trouble is within wiper, install a new one.

MISCELLANEOUS PARTS

2915. Always disconnect the battery cable before removing the gasoline gage or disconnecting any wires on the back of the instrument panel.

2916. Under no circumstances should the shatterproof glass used in Model A windshields be drilled or the black seal around the edges ground off. The windshields are made of two layers of glass with a center layer of plastic material, all of which are thoroughly cemented together under heavy pressure while hot. Grinding off the black seal or drilling the glass exposes the center plastic layer, causing it to deteriorate.

2917. See that all body bolts are drawn down tightly. Because of the settling of the body and the compression of the anti-squeak material between body and frame, body bolts can be taken up during first few months of service.

2918. When changing a speedometer or speedometer cable time will be saved by removing distributor from cylinder head. This permits pulling the instrument panel back sufficiently far to allow easy access to speedometer or cable.

2919. To clean sport top material use H&H soap or soap of similar ingredients, in hot water. (Procure soap locally.) Apply with stiff brush until lather is formed, then rinse with clear cold water. To remove hand-marks, soil, and the like, use art gum.

2920. Should the brown seal grain leather on the Fordor car become dull in appearance it can be brightened by briskly wiping it with a cloth moistened with benzol or gasoline. Care should be taken not to use the benzol or gas too freely.

2921. The distance from the back of the driver's seat to the steering wheel rim measures 13½ inches, this adjustment having been found most satisfactory for the average driver. If, however, an owner prefers to have the seat moved closed to the wheel, it can be easily done by removing hinge pin, loosening nut and reversing the seat hinge. This moves the seat 1¾ inches closer to the wheel. After making adjustment be sure to replace cotter key in hinge pin and tighten lock-nut. If desired, the front passenger seat can be moved up in the same manner.

CHAPTER XXVI

FRONT-WHEEL DRIVE AUTOMOBILES

3001. Without question the most radical development in a quarter century of American automobile building is the recent advent of front-drive passenger cars (Figure 213).

3002. While front-drive is new to the manufacture of American automobiles, the principle itself is lost in the dim past of unwritten history. Vehicles propelled by animal power have had "front-drive" ever since man first learned to use animals for hauling. The only notable exception is the wheelbarrow which is without doubt a much more recent invention than the drag or its successor the 2-wheeled cart of ancient times.

3003. Nor is the front-drive automobile new in itself. It would be difficult to say who built the first one, but at least it can be stated that the first front-drive car to attract attention in the United States was a racing machine built and driven about 1905 by Walter Christie, a New York engineer. Other Christie racing cars followed and all were successful in the dirt track and road races of that day.

3004. During the period Christie developed a gasoline-propelled unit for horse-drawn steam fire engines. The gasoline engine and its attendant mechanism were mounted at the front, thus eliminating the horses but retaining the steam pumping machinery. Many of these units were used and gave good service for years until finally displaced by more modern types of fire apparatus.

3005. Until recently, front-drive development during the intervening years was mainly concentrated in the truck field. For the past 20 years some front-drive trucks have been built in Europe, while in the United States there have been a few makes of trucks with 4-wheel drive; this of course means that those vehicles have front-drive as well as rear-drive.

3006. Within the past few years several front-drive cars have been developed in Europe and a few have been put into production in a limited way. About four years ago, Harry Miller, well-known Pacific Coast builder of racing cars, produced a front-drive racing car which proved so popular that since then a number have been built.

3007. These front-drive racing cars handled so well at high speed, especially on turns, and they looked so smart, that many of those who saw them in action were prompted to raise the question, "Why not front-drive passenger cars?" Thus it was automobile racing, or rather the success of Miller's front-drive racing cars, which fanned up in this country the present interest which many people have in the front-drive question.

3008. Is front-drive better? Is rear-drive out of date? Will all cars at some time in the future be driven from the front? The automotive industry is divided as to the answers to these questions. A certain enthusiastic minority gives an emphatic "yes" to all three; the majority, however, answer "no," while others take the middle ground, remarking, "we shall wait and see."

3009. The facts for and against are readily set down on paper, although complicated by many variables, but even after all the arguments have been carefully weighed, it is still impossible at this early date to say just how popular front-drive cars will eventually become, because nobody can accurately measure public psychology. In short, just how will the public at large appraise the advantages and disadvantages of front versus rear drive after it has become thoroughly acquainted with the features of both? Nobody knows the answer, but the following discussion will assist the reader in forming his own opinion.

COMPARISON OF FEATURES OF REAR-WHEEL AND FRONT-WHEEL DRIVES

3010. Let us begin by recalling the salient features of the conventional rear-drive automobile: From front to rear the units employed in propulsion are engine, clutch, transmission, drive shaft, pressed-steel rear axle within which is the bevel gear and differential assembly and the axle drive shafts. Let us say also that it has a straight eight engine, a wheelbase of 130 inches, 30-inch tires, and an overall height of 72 inches.

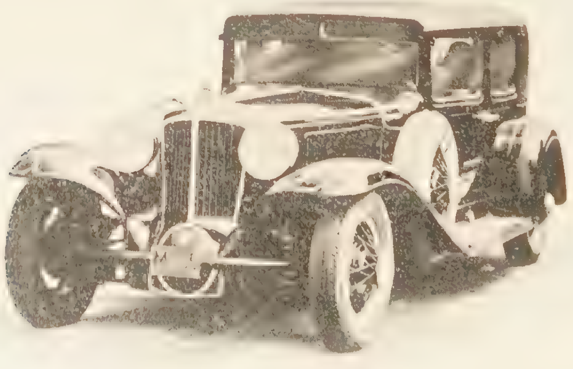


Figure 213.—General view of 5-passenger Cord front-drive brougham

3011. Now let us consider a similar front-drive. The units from front to rear are: Differential assembly, transmission, clutch, engine (Figure 213). The overall height is 61 inches with the same body headroom as in the rear-drive but the wheelbase is longer, say 137 inches because the clutch, transmission and differential assembly stand ahead of the engine. The increase in wheelbase might be even greater were it not for the fact that the rear of the engine is recessed into the dash (Figure 214).

3012. In the front-drive, the differential assembly, transmission, clutch and engine are built to form a single unit (Figure 215 *A* and *B*) mounted in the frame, a short cross shaft equipped with two universal joints running from the differential to each wheel. The Ruxton has half-elliptic front springs and an I-beam front axle which is carried beneath the differential mechanism, while the Cord has dual quarter elliptic front springs and a tubular front axle which curves out in front of the differential unit. On both cars a simple I-beam rear axle is used with half-elliptic springs.

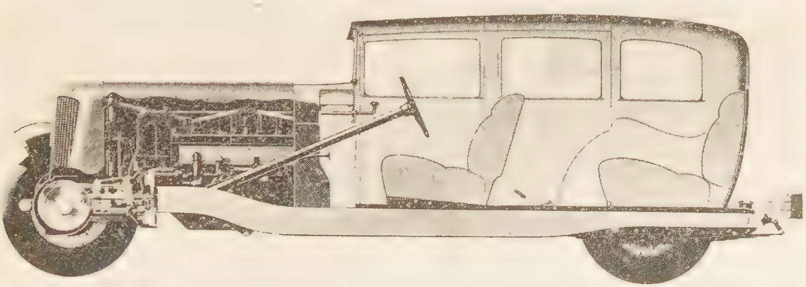


Figure 214.—Section through Cord front-drive car

3013. With the characteristics of the two types of cars in mind, it should be noted that those who favor front-drive emphasize the following structural advantages: Drive at the front where it logically should be; a 100 per cent unit power plant; a lower car with a lower center of gravity; straight frame side rails (without a kickup at the rear axle) which provide an ideal foundation for the body; reduced unsprung weight especially at the rear where a simple I-beam rear axle replaces the conventional pressed-steel rear axle containing the differential assembly; elimination of the long propeller shaft

3014. Those who prefer rear-drive reply that these advantages are not important, and certainly not sufficiently important to warrant the extra expense and complication, not to mention the necessarily longer wheelbase and resultant increased weight.

3015. In reply, the front-drive proponents insist: (1) that theirs is the simpler construction; (2) that all of the major units are bolted together to form an integral whole; (3) that the long propeller shaft is eliminated with

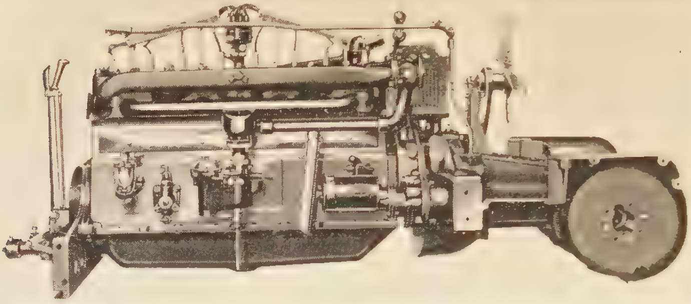


Figure 215, *A*

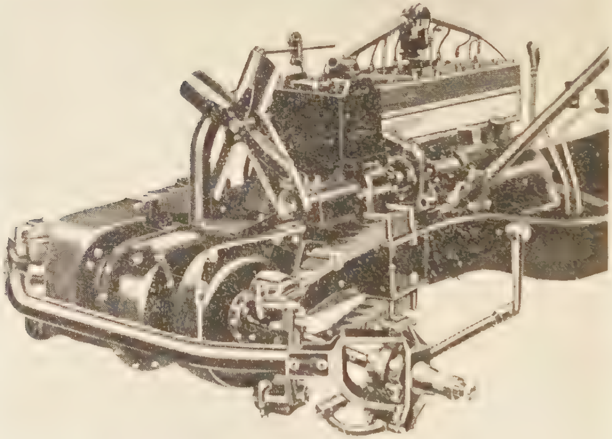


Figure 215, *B*

Figure 215.—Two views of Cord front-drive car: Upper—side view of power plant. Lower—front view of complete front assembly

its tendency toward vibration; (4) that the relatively complicated rear axle is replaced by an I-beam; (5) that the differential assembly is removed from the road and placed up on the frame; (6) that in consequence the bevel pinion and ring gear may be made as heavy as desirable for maximum silence, because so doing does not add to the unsprung weight; (7) finally, a few engineers believe that eventually front-drive construction will be developed to the point where it is cheaper than rear-drive.

3016. Rear-drive engineers point out that only one or two universals are required with their construction whereas four are necessary with front-drive, that comparing front- and rear-drive cars point for point, front-drive *is* more complicated and more expensive including such minor details as gear-shift mechanism, starter crank mechanism and so forth.

RELATIVE ACCESSABILITY FOR REPAIRS

3017. Each proponent claims to have the more accessible construction from a repair standpoint. Rear-drive experts ask, "What about your front-drive when it hits a telegraph pole, with all that machinery sticking out front?" To which the front-drive men retort: "Even so, wouldn't you rather crack up a differential than a cylinder block?"

3018. All of which shows that there are many good arguments on both sides, although in fairness to the reader it must be added that the engineers who prefer rear-drive greatly outnumber those who prefer front-drive. Perhaps this is because front-drive is so new its advantages are generally unappreciated and perhaps it is because the advantages of rear-drive really outweigh those of front-drive.

3019. So far we have confined out attention to a comparison of structural advantages pro and con, but of far more importance is the question as to how these differences in structure affect the actual performance on the road.

3020. Naturally, the first question is: "What actual benefit if any is noted when you find yourself behind the wheel of a front-drive car? What are your sensations? How does it differ? To answer these questions it must first be recalled that the front-drive pulls the car over the road while the rear-drive pushes it. On a straight, hard, dry road under normal driving conditions it is doubtful whether anybody can tell by the action of the car whether the drive is at front or rear. But if some crisis arises which causes a skid the front-drive car can be pulled out of it by opening the throttle, always assuming that the driver has the opportunity to open the throttle under the conditions of the crisis for these conditions may demand braking instead.

3021. This ability of the car to drive out of a skid should be obvious but if not, try pushing a ruler over a table with the finger at the back end. Note that if the ruler starts to "skid" considerable effort is required to maneuver it straight again whereas if the ruler is pulled over the table by a string, and the ruler is then swung sideways, continued pulling will soon bring it back so that it again moves straight along its line of motion.

3022. On a slippery surface of any description whether wet, icy, snowy, muddy, sandy, oily, or covered with loose gravel any tendency to skid is immediately corrected. For example: in excess of a mile a minute the author has deliberately zigzagged a front-drive car from side to side down a wide loose gravel road with full control of the car. Perhaps this stunt can also be performed with a rear-drive, but if so, there are few with the nerve to try it. A front-drive car will pull through deep mud more handily than a rear-drive.

3023. Rear-drive experts, after reading the foregoing paragraph, remark: "What of it? Everyday experience proves that rear-drive cars will negotiate the roads described quite safely and satisfactorily. After all, skidding is fairly uncommon. The improved performance of the front-drive under the conditions described is not important." And those favoring front-drive would retort, "But it *is* important."

PULLING VERSUS PUSHING POWER

3024. Because the car is pulled, it is the author's impression that the front-drive is steadier at high speed on rough roads. It has no tendency to dive off the course after hitting a severe bump; to which those preferring rear-drive say: "Who wants to drive over bumpy roads at 60 or 80 miles an hour?" Front-drive engineers reply, "All roads are more or less rough; therefore front-drive is steadier on all roads."

3025. Because of its low center of gravity plus the fact that the wheels are pulling in the direction they are being steered it is doubtful whether anybody will dispute the claim that a front-drive can be taken around a curve faster without skidding than can be done with a comparable rear-drive car. Front-drive engineers say this is important, whereas rear-drive experts insist that on the majority of curves the rear-drive car can be taken around faster than is safe from a visibility standpoint.

3026. Front-drive experts state that a blow-out in a front wheel is not as serious as with rear drive. Closing the throttle of a front-drive suddenly at high speed has no effect whatever on the course of the car. This statement is made because prior to the advent of front-drive passenger cars many believed that to do this would put the car into a disastrous skid. The steering action of a front-drive is just as easy as it is with a rear-drive, the delivery of power through the front wheels having no effect on steering action.

3027. Other things being equal, the front-drive must have a higher maximum speed because its wind resistance is less because it is lower. Assuming that the frontal area of a front drive is 22 square feet as against 26 square feet for a comparable rear-drive, if the latter has a top speed of 80 miles an hour the former has a maximum of about 85 miles an hour.

3028. Front drive men say that their flat frame is a big advantage over the rear-drive frame which has a kickup over the rear axle. Also the front-drive frame may be ideally braced because there is no propeller shaft to interfere with the design of the cross members. It can not be denied that the sturdier the frame the fewer the body noises and so, other things being equal, if the front drive frame is stiffer the bodies mounted on it must be more satisfactory. But until actual data on this point is available it can not be settled.

UNSPRUNG VERSUS SPRUNG WEIGHT OF CARS

3029. One of the chief advantages urged for front-drive remains to be mentioned and that is, small unsprung weight. This term refers to the weight of those units below the springs. Sprung weight on the other hand is the weight supported by the springs.

3030. In a front-drive the unsprung weight at the rear must be less than in the conventional rear-drive, because an I-beam rear axle takes the place of the pressed steel axle containing the differential assembly. The sprung weight at the front may also be less. Although the outer ends of the front-drive shafts add something to the unsprung weight, this is offset by mounting the front-brake mechanism just outside the differential mechanism instead of at the wheels. The front unsprung weight on the Cord car is 360 pounds and the rear unsprung weight 350 pounds. On a "similar" rear-drive car these respective weights are 390 and 460 pounds.

3031. It is well known that when the wheels encounter bumps they have a tendency to bounce off the road. The rougher the road and the higher the speed the greater the tendency. The stiffer the springs the more successful they are in maintaining wheel-to-road contact. Likewise, the less the unsprung weight the more successful the springs must be in maintaining road contact. Obviously, the less the bouncing the better the car "holds" the road.

3032. It must also be noted that the more flexible the springs the less the passengers are jolted on the average bump, although this statement assumes adequate shock absorbers.

3033. Judging solely by the figures just quoted it is apparent that the Cord car, because of its reduced unsprung weight must hold the road better at high speed than the "comparable" rear-drive car previously mentioned. Likewise, the somewhat more flexible springs on the Cord car should provide a corresponding improvement in riding quality, although it is still too early to appraise accurately the actual importance of the advantages just discussed.

COMPARATIVE HEIGHT AND APPEARANCE

3034. As previously mentioned, rear-drive engineers insist that all the front-drive features are actually of but slight importance, and are more than offset by the greater complication. They say that rear drive cars are already low enough, that a lower car is disagreeable to drive, that the rear-drive is equally smart in appearance, especially if due allowance is made for the novelty of lowness in the front-drive, that a front drive is too low to get in or out of conveniently when parked at the curb, and so on.

3035. In fairness to the rear-drive car it must be noted that it can be designed to possess practically all the advantages claimed for the front-drive car except the front-drive itself. To explain this point, let us compare the heights of some front- and rear-drive designs. The factors which control the height of the conventional rear-drive car are roughly as follows: Wheel radius, 15 inches; differential housing radius, 6 inches; distance from differential housing to base of rear seat cushion to provide spring play—car loaded, 5 inches; thickness of seat cushion, 9 inches; cushion to roof, 37 inches, making the overall height 72 inches (Figure 216).

3036. By using worm drive this height may be reduced an inch or more (Figure 217).

3037. By applying the front-drive principle to the rear end—that is, by attaching the differential assembly to the frame and transmitting the power from differential to rear wheels by short cross shafts, each equipped with two universals and supporting the wheels on a tubular axle bowed to the rear, the overall height becomes 66 inches (Figure 218). Note also that this

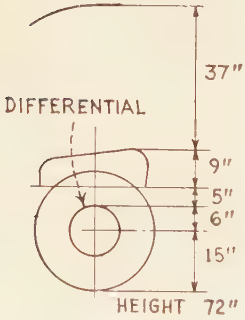

37"
DIFFERENTIAL
9"
5"
6"
15"
HEIGHT 72"

Figure 216

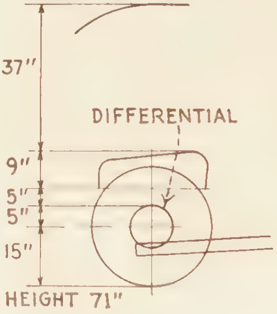

37"
DIFFERENTIAL
9"
5"
5"
15"
HEIGHT 71"

Figure 217

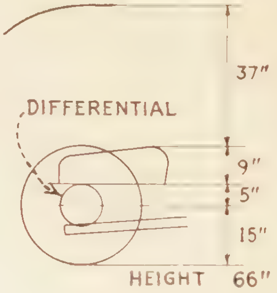

37"
DIFFERENTIAL
9"
5"
15"
HEIGHT 66"

Figure 218

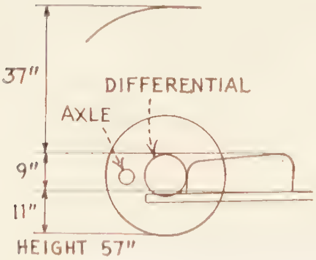

37"
DIFFERENTIAL
AXLE
9"
11"
HEIGHT 57"

Figure 219

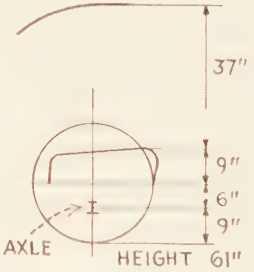

37"
9"
6"
9"
AXLE
HEIGHT 61"

Figure 220

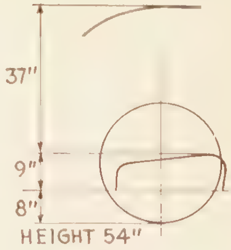

37"
9"
8"
HEIGHT 54"

Figure 221

Figure 216.—Rear elevation of conventional rear-drive with bevel gear

Figure 217.—Rear view of rear-drive with worm gear

Figure 218.—Rear-drive with worm gear and differential attached to frame

Figure 219.—Rear-drive with worm gear and differential placed to rear of cushion, where it is attached to frame

Figure 220.—Rear end of conventional front-drive

Figure 221.—Rear end of front-drive when rear axle is eliminated

construction makes the rear unsprung weight about the same as for the front-drive car.

3038. By moving the construction just described to the rear of the rear seat cushion (Figure 219), the height of the rear-drive might be cut to 57 inches. Although in this case and perhaps in the preceding one, the propeller shaft might interfere with the floor-board and frame construction.

3039. With front-drive, as discussed throughout this chapter, the overall height is 61 inches (Figure 220).

3040. With front-drive and independently sprung rear wheels—that is, each rear-wheel spindle supported direct by springs but without an axle running between them—the overall height of the front-drive car might be cut to 54 inches (Figure 221). For various reasons this car is probably too low. For one thing the frame-to-road clearance is only 8 inches which is hardly enough to prevent scraping the frame on some bumps. Also the floor boards would be attached to the lower flange of the frame instead of the upper, and therefore passengers would have to step over the frame in entering or leaving the car. In addition the height of the door opening would be cut down and note in this connection that regardless of this disadvantage a car can be so low that it is troublesome to enter it at the curb.

3041. Thus it does not seem *feasible* to build front-drive cars quite as low as it is *possible* to build them. On the other hand, it does appear feasible to build rear-drive cars several inches lower than they now are. Although perhaps it will never be possible to build a rear-drive quite as low as a front drive, it appears possible to build the former as low as anybody is likely to want it.

DESCRIPTION OF THE NEW CARS

THE RUXTON FRONT-WHEEL DRIVE CAR

3042. Distinction of appearance is an outstanding characteristic of the Ruxton front-drive car, powered with an eight-in-line engine. While headroom is greater than usual, 42 inches from floor to roof, the car is unusually low due to its front-drive construction, the height from road to roof being less than 60 inches (Figure 222). Road clearance is 8 inches.

3043. It is fitted with a powerful 8-cylinder engine, has a 3-speed transmission.

3044. The clutch is placed forward of the engine, and ahead of the clutch is a 3-speed and reverse sliding gear transmission, with the differential housing directly attached to it. Each drive shaft is fitted with two universals. The front axle is an I-beam and the rear axle is tubular.

3045. To reduce the overall length of the power plant, as measured from front wheels to dash, the 3-speed sliding gear transmission on the Ruxton front-drive is placed directly over the differential mechanism. As shown in Figure

223, *A* and *B,* the worm drive pinion is placed in the center of the transmission case. While the transmission looks unusual, in principle, it does not differ from the conventional three-speed design except as to position of gears. The worm pinion is placed in the center of the elongated main shaft with annular ball bearings at either side of the pinion. The rear end of the main shaft is splined and carries the gear which engages high and second in the

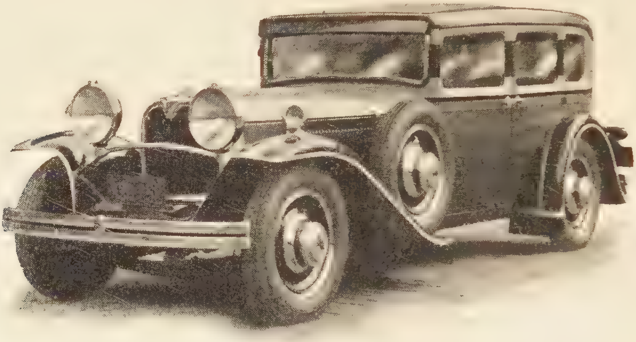


Figure 222.—Ruxton 8-cylinder front-drive car with overall height of 60 inches

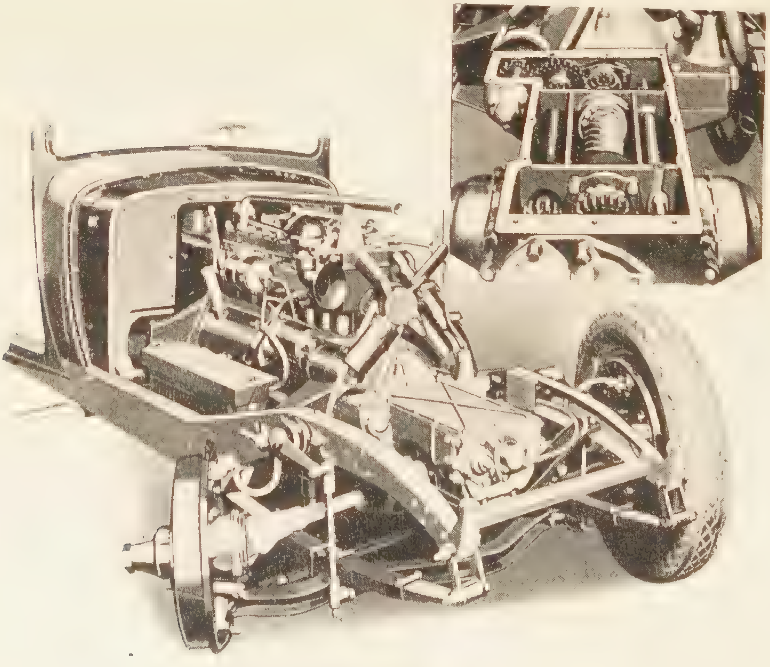


Figure 223.—Two views of Ruxton power plant showing particularly the position and construction of the transmission

usual manner. Likewise, the front end of the main shaft is splined and fitted with the gear which provides low and reverse. In other words the construction may be summed up by saying that it resembles a conventional transmission cut in two verically between the two sliding gears and the worm gear inserted at this point. Because of this construction the countershaft is in the same horizontal plane as the main shaft instead of being placed below it.

THE CORD FRONT-WHEEL DRIVE CAR

3046. Although only brief information was available concerning the Ruxton car when this was written, full details were available regarding the Cord car. The Cord has a Lycoming 8-in-line engine with a bore and stroke of 3¼ by 4½ inches, and a wheelbase of 137⅝ inches. The overall height of the sedan is 61 inches while the (convertible) phaeton-sedan is 61 inches, both with standard headroom from cushion to roof of 38 inches and road clearance of 8½ inches at the center. Rear-drive cars have an overall height of about 70 inches.

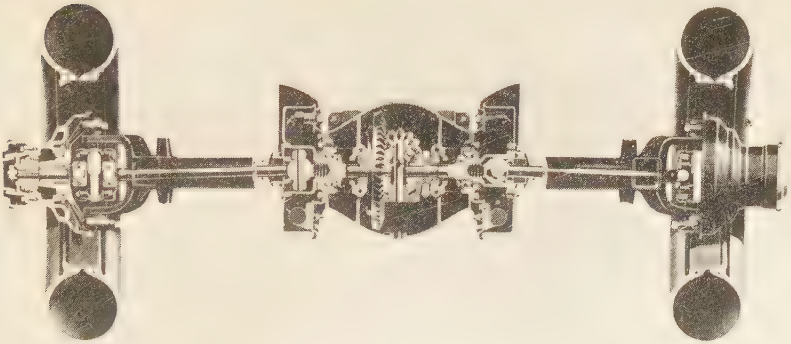


Figure 224.—Front-drive mechanism of Cord car

3047. The hood is long, 46 inches, and the sweeping one-piece front fenders with a length of 80 inches are described as the longest on any automobile. Unusual two-unit front bumpers are attached to the axle, harmonizing nicely with the chromium rimmed differential cover and the shuttered radiator of unique outline.

3048. An axle shaft equipped with two universal joints runs from the differential to each wheel (Figure 224). The front axle is a tubular type, curved forward so as to clear the differential housing. The drop forged yokes at its ends are large and placed at an angle to permit placing the outer universal direct in line with the king-pin axis so that steering the front wheels has no effect on the delivery of power or conversely. There is no king pin, the spindle yoke being swiveled on the axle yoke by two bronze-lined steel-backed bushings, and carried on a ball thrust bearing.

3049. Great stress is laid on the fact that the outer universal is a constant velocity type. To make the importance of this point clear it must first be explained that when any two shafts are connected by a universal, if the driving shaft is operated at constant speed, the speed of the driven shaft will only be uniform when the two shafts are in line. If the driven shaft makes an angle with a driving shaft, the former will alternately run faster and slower than the latter during each half revolution. This variation increases in magnitude as the angle of the joint increases. Consequently, if a single universal were used at the king pin there would be an objectionable variation in driving effort when the wheels were steered from the straight-ahead position.

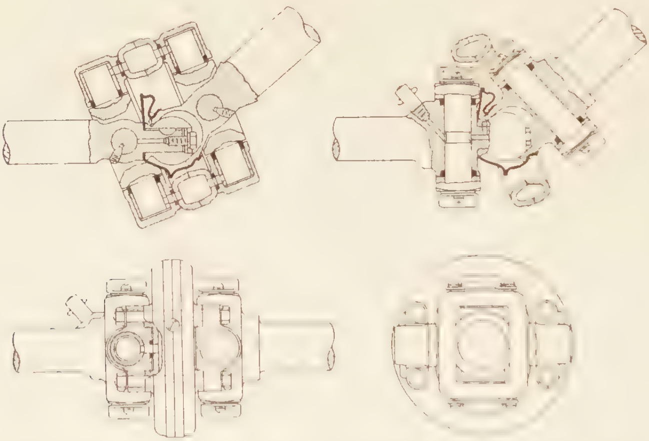


Figure 225. Four views of the Cord constant velocity outer universal. The driven shaft is at the left. It is really two universals in one, alined by a dust proof ball-and socket joint. The central hollow ring carries the trunnions of both joints. This hollow chamber supplies lubricant to all surfaces except the ball and socket joint which is oiled by Alemite connection

3050. To secure constant velocity it is necessary to use two universal joints, because the second counteracts the effect of the first, permitting the driven shaft to run at the same speed as the driving shaft for a wide variation of angle. Thus the outer universal in the Cord is really two universals combined into a single unit, distinguished by compactness and simplicity. This patented universal is illustrated in Figure 225, and the caption accompanying the illustration describes its details. Drive may be described as full floating. Two taper roller bearings, mounted on a hollow spindle, carry each front wheel. A short drive shaft from the outer universal runs through the spindle and is splined to a cap bolted to the wheel hub. At the universal end this shaft is carried in a Hyatt roller bearing.

3051. Caster and camber are 1½ degrees. Toe-in is described as zero, although it is understood the wheels toe out a trifle because application of power tends to make them toe in. Thus if they toe out slightly standing still they will be straight when the engine is driving. The steering gear is a Gemmer worm and roller. Drag-link and tie-rod are ball-jointed.

3052. The front axle is attached to dual quarter elliptic springs. The forward curve of the axle makes the customary half elliptic impracticable. The front end of the frame is kicked up so as to provide suitable clearance for drag-link and tie-rod. The springs point outward at an angle, thus permitting the frame to be narrower than usual at the front, and this in turn allows an unusually short turning radius, 21 feet, for a car with a 137⅝-inch wheelbase. The constant velocity outer universals, of course, permit sharp cramping of the wheels without introducing any difficulty.

3053. The 58-inch front tread also assists in providing a small turning circle. The rear tread is also wider than customary, 60 inches, to allow sufficient rear seat width, as the low frame places the cushion between the wheels.

3054. The angular mounting of the springs would twist the frame side members were it not for the fact that the front engine support is bolted directly to the two box-like frame extremities which carry the springs. Spring torsion is more than adequately resisted by the engine support without affecting the frame side members. Incidentally, the engine is mounted at four points.

3055. When one wheel passes over a bump, the consequent raising of the axle on this side to twist the quarter elliptic springs. If conventional metal shackles were used, the resultant stress on both the springs and the shackles would be objectionable. The problem has been neatly solved by mounting the ends of these springs in rubber shock insulators which allow sufficient play to prevent measurable twisting of the springs.

3056. Hypoid gearing transmits the power from transmission to differential. Whereas in rear-drive practice the hypoid pinion is placed 2 to 2½ inches below the axis of the rear gear, the opposite is Cord practice. The pinion is 2 inches above the ring gear axis to secure standard road clearance under the flywheel housing.

3057. The Cord Division of the Auburn Automobile Co., Auburn, Indiana, makers of the Cord automobile, which is named after E. L. Cord, president, emphasizes the point that pinion and ring gear and differential mechanism are unusually large because considerations of unsprung weight impose no limitations on the size of these parts as it often does in the rear-drive car where these members are within the unsprung axle. As these units on the Cord car are carried above the springs, they have no effect on the unsprung weight (Figure 226).

3058. The differential assembly is carried on two taper roller bearings. At each side, the driving member of the inner universal, the flange that supports the brake drum, and the short shaft running to the differential drive gear are ingeniously formed from a single forging which is carried in an annular ball bearing.

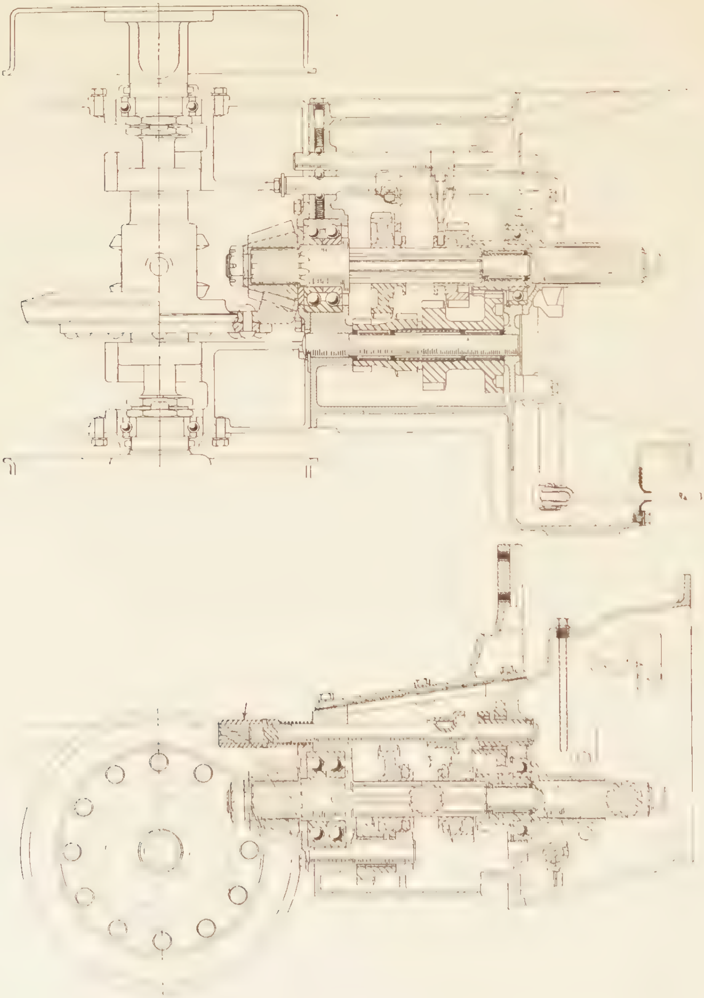


Figure 226. Transmission and differential assemblies: Upper—horizontal section; lower—vertical section. The pinion is mounted on the end of the main shaft. The starting crankshaft is placed above the main shaft

3059. Optional gear ratios are 4.076, 4.418 and 4.818 to 1. The speedometer is driven from a gear adjacent to the differential mechanism and therefore is unaffected by a change in axle gear ratio.

3060. The rear axle is an I-beam (Figure 227), with a raised center portion which gives 8½-inch road clearance. Rear-wheel bearings are taper roller. Rear springs are half elliptic.

3061. The transmission, which is bolted to the rear of the differential housing, has the countershaft in the same horizontal plane as the main shaft. The shifter shafts are placed to the right of the main shaft. The countershaft cluster is carried on Hyatt rollers. The clutchshaft is mounted in an annular ball bearing. The back end of the main shaft fits into a Hyatt roller spigot bearing while the front end is carried in a large, dual annular ball, an integral splined extension on the front of the main shaft supporting the hypoid drive pinion.

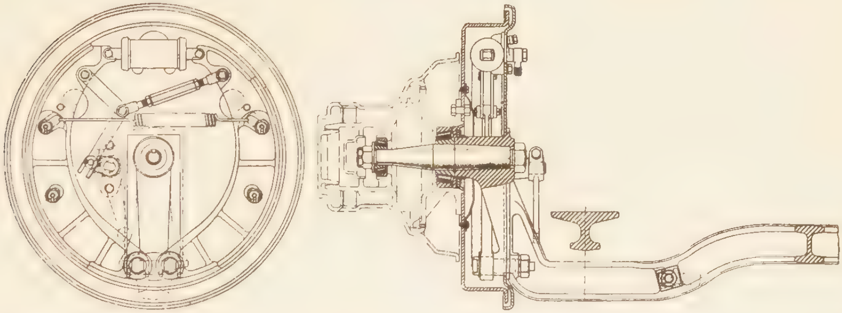


Figure 227.—The rear hydraulic brakes are mechanically linked to the parking lever

3062. Obviously, with a complete reversal of the power-plant mechanism, special provision must be made for the hand starting crank. The crank handle attaches to a shaft reached by removing a cap near the top of the differential hand hole cover. The shaft runs through the top of the transmission to a gear which meshes with the master gear in the transmission. The cap is attractively decorated with the Cord crest.

3063. Gears are shifted by a knob attached to a sliding rod extending from the instrument board. The rod passes between two rollers at the front, right of the engine and from thence attaches to the gear-shift lever. This simple mechanism permits gear shifting in the usual manner, except that the so-called standard shift is not used. High is forward to the right, second rearward to the right, first forward to the left, and reverse rearward to the left.

3064. Lockheed internal hydraulic brakes are used with 60 per cent braking power in the front—to take advantage of "weight shift" to provide maximum stopping ability.

3065. A conventional Long single-plate clutch is used. The clutch is actuated by a shaft which runs along the left side of the engine.

3066. The hand-brake lever is placed well forward so that the driver's compartment is unencumbered. This lever expands the rear hydraulic brake shoes by mechanical linkage.

3067. A flat gasoline tank at the rear holds 20 gallons. Fuel is fed by an A C pump. A $1\frac{1}{4}$-inch Schebler dual carburetor is used with a dual manifold having dash-adjustable heat control. Electrical equipment is Delco-Remy. The battery is conveniently placed just forward of the cylinder block. The exhaust pipe is carried down in front and the muffler is placed to the right of the crankcase. The muffler is provided with a bypass. The frame is an exceptionally interesting unit. Except for the kickup at the front, the side rails are straight all the way to the rear, thus providing an ideal foundation for body mounting. The absence of a propeller shaft permits an unusually heavy X-shaped brace at the mid-section. In addition, there are two cross-members at the rear, and the engine support serve as two cross-members at the front. Frame side rails are 7 by 3 by $\frac{7}{32}$ inches. This frame is unusually rigid and should go far toward insuring continued body silence.

3068. Except for minor changes incident to the application of front drive, the engine is a standard Lycoming design with such features as Nelson Bohnalite pistons, pressure lubrication, and a five-bearing counter-balanced crankshaft. Standard compression ratio is 5.25 to 1.

3069. Bearing in mind that the power plant is turned around, the Lanchester vibration dampener is found at the rear, being fully housed in a sheet-metal cover. The timing chain, however, is placed at the front or flywheel end. A longer life for the longer timing chain should result because the flywheel end is not appreciably subject to torsional crankshaft vibration.

3070. As the engine is reversed, it rotates anti-clockwise, viewed from the front, whereas clockwise rotation is customary. However, as the hand crank operates through a gear, its rotation is conventional.

3071. The fan bracket is integral with the transmission cover, permissible as the shifter shafts are to one side. The fan is driven by Vee belt from a lay shaft operated by the timing chain. The rear of this shaft drives the water pump and generator. Bijur lubrication is supplied to the fan, the fan drive pulley, the clutch throwout bearing, the water pump, and of course also to the rear-spring shackles which are metal.

3072. The radiator is a Modine with flat, finned vertical tubes. Radiator shutters, thermostatically controlled, embellish the front end of the car and there is also a water thermostat in the water outlet from the cylinder block.

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